The Natural Resources of Rajasthan

Edited by

M.L. ROONWAL

With the assistance of

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Volume 1

Part 1 and Part 2 (in part :
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Foreword

This book has resulted from the Symposium on the Natural Resources of Rajasthan, which was held at the Jodhpur University, Jodhpur, from 23-26 October, 1968. The holding of the Symposium was made possible through generous grants received from the Jodhpur University and the University Grants Commission. It fulfilled a real need. The response, both in the contribution of papers as well as for the Exhibition, was beyond our expectations, and we are pleased that this was so. For the Symposium itself, a printed *Abstracts of Papers* was provided to all the participants. But it was widely felt that the publication of the fuller papers which were read would make a valuable contribution to our knowledge of the natural resources of the region, particularly the arid region, and also to the general subjects concerned, namely, fauna, flora, hydrology, solar and wind power, mineral resources, geology, soils, climate, etc.

The only comparable event was the "Symposium on the Rajputana Desert" which was held in New Delhi in 1952 by the National Institute of Sciences of India (published as the *Bulletin of the National Institute of Sciences of India*, New Delhi, No. 1, v+302 pp., 1952) in which a wide field was covered. Since then, certain events have happened which resulted in the intensification of research work in Rajasthan. These are the establishment, at Jodhpur, of the Central Arid Zone Research Institute and the University of Jodhpur.

Furthermore, organisations, both of the Rajasthan State and the Central Government, such as the all-India Surveys (the Zoological Survey of India, the Botanical Survey of India and the Geological Survey of India), the Exploratory Tube Wells Organisation, the Rajasthan Ground Water Board, the Mining and Geology Department of Rajasthan, the Fertilizer Corporation of India, the Atomic Energy Establishment, the Oil and Natural Gas Commission, the Hindustan Salts Ltd., and a number of other organisations, have carried out intensive investigations in the region. As a result, a large body of extremely valuable new knowledge has accumulated, and this is abundantly reflected

in the present Symposium. A comparison with the 1952 Symposium will make this evident. Special fields in which new knowledge has been acquired are : the fauna and flora, the pests of agricultural crops (insects, nematodes, rodents), animal and plant physiology in deserts, surface and ground water resources, power resources (e.g., wind, solar and atomic energy), the reclamation of saline soils, the fertilizer and other minerals, the oil and natural gas resources, physiography, geomorphology and land utilization, the nature of soils, and the study of climate. All these topics were dealt with in the Symposium.

I acknowledge with gratitude the valuable services rendered by all those who assisted me in editing this volume, especially Dr. S. Johnson, Dr. R.S. Gambhir and Mr. D. Banerjee on whom fell the major burden of this laborious process. Several papers had to be considerably reduced due to considerations of space. In a few cases the authors failed to supply the full papers, and these have been given as abstracts only. I believe that the book will serve as a valuable, and in fact an indispensable, work of reference and will, I hope, be widely used. As far as I know, such a compendium of natural resources does not exist for any of the Indian States.

M. L. Roonwal
General President
and
Vice-Chancellor, Jodhpur University

Jodhpur
May, 1969

Postscript

This book has, I regret, taken much too long in printing, much longer in fact than was expected. This was due to reasons quite beyond our control. In some cases the authors have updated the material in the proof stage. The successive Vice-Chancellors (Mr. V.V. John, Dr. P.N. Masaldan and Prof. S.C. Goyal) did all they could to assist in the printing, and I acknowledge their generous help. The Manager of the Jodhpur University Press, Mr. M.M. Mathur, and the Secretary, Press Management Committee, Mr. M. S. Maheshwari, have given their fullest cooperation, and I acknowledge this assistance with thanks.

Jodhpur
January, 1977

M.L.R.

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Paper of H.R. Ganesan, pages 1107-1119.

Page 1107, line 4 : For "H.R. Ganesh", read "H.R. Ganesan".
Pages 1109, 1111, 1113, 1115, 1117 and 1119 :
In page headings :
For "GANESH", read "GANESAN".

The Natural Resources of Rajasthan

Volume 1

PART 1

Official Matters

1. ADDRESS OF THE GENERAL PRESIDENT

By

M. L. Roonwal

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Vice-Chancellor, Jodhpur University, Jodhpur

Delivered on 23rd October, 1968, to the Symposium on Natural Resources of Rajasthan, Jodhpur

Delegates to the Symposium, Distinguished Guests,
Ladies and Gentlemen,

Introductory

Sixteen years ago, in March 1952, the National Institute of Sciences in India in cooperation with the Government of India held, in New Delhi, a "Symposium on the Rajputana Desert", and the proceedings of that important symposium were published by the Institute in September 1952 in an impressive volume of nearly 300 pages.* It dealt with the many problems of the western desert which, it is feared, is marching at a rapid rate towards the east. As the title indicates, the symposium was confined to the desert portion of Rajasthan.

Scope and Coverage

Rajasthan is one of the largest States of India, with an area of 3,42,274 sq. km. and a population of nearly 20 million. Situated on our western border, it has great strategic value. The western two-thirds of it is a dry and desert area which is rather unproductive and poor in agriculture, while the eastern one-third, demarcated by the Aravalis, *is an area which is wetter and is also agriculturally more productive.* The western area contains vast grasslands and sustains large herds of cattle, sheep and goats which form the backbone of its economy. The people are traditional and this is one of the reasons why Rajasthan has one of the lowest per capita income among the States of India. Even for its small population, the annual food production is low and falls

*Rajasthan Desert—*Bull. National Inst. Sci. India*, New Delhi, No 1, v + 372 pp., 2 pls, 1952.

short of the actual requirement by nearly 0.2 million tonnes as against the requirement of nearly 0.6 million tonnes.

To add to this dreary picture there is a fear that the Indian desert is spreading outward in a great convex arc through Ferozepur, Patiala and Agra towards Aligarh and Kasganj at the rate of about half a mile per year during the last 50 years and is encroaching upon approximately 50 sq. miles of fertile land every year. While this estimate, as given by the Planning Commission some years ago, may be very approximate and is not universally admitted, there is no doubt that the desert conditions have been deteriorating.* This process has to be checked as the desert has been advancing due to lack of adequate afforestation and other means. This point was made sufficiently clear in the National Institute Symposium which I have referred to earlier.

It has been felt for some time that a comprehensive survey of the natural resources of the entire State of Rajasthan would be useful for the all-round development of the State on a scientific basis and for future planning.

The present Symposium has been divided into five major sections, namely :

(A) Plant Resources of Rajasthan.
(B) Animal Resources of Rajasthan.
(C) Physical and Power Resources of Rajasthan.
(D) Mineral and Industrial Resourses of Rajasthan.
(E) Geology, Soils, Geography and Climate of Rajasthan.

Within each of these major sections, various other items of importance have been dealt with and I will give here only a few of them in order to let you know the coverage of the Symposium.

The Plant Resources Section deals with such topics as the floral composition of Rajasthan, plants useful to man, forest wealth, and water relations of plants.

The Animal Resources Section deals with the faunal composition of Rajasthan, animals useful to man (such as fish and fisheries, sheep, goats, etc.), animals harmful to man (such as rats and other rodents, locusts, termites or white-ants, helminth parasites, and animals which spread disease), and wild life.

The Section on Physical and Power Resources deals with such topics as solar and wind energy, atomic energy, etc.

The Section on Mineral and Industrial Resources deals with oil

*There is a paper by G. S. Roonwal, in Section E of this Symposium, on the drying up of Rajasthan.

and natural gas, coal and lignite, minerals including atomic minerals, building stones, fertilizer minerals and salts.

The Section on Soils, Geology, Geography and Climate deals with such topics as geology of Rajasthan, palaeontology, surveys of ground water resources, soils, urban and rural land use and climatology.

The meetings of the various Sections will be held simultaneously under their respective Chairmen. Each paper will be followed by a discussion. We are fortunate in having distinguished experts as our Chairmen. They are :

1. Dr. Mukhtar Singh, Director, Central Arid Zone Research Institute, Jodhpur, as Chairman of Section (A) on Plant Resources.

2. Professor S. D. Misra, Professor of Zoology at the Jodhpur University, as Chairman of Section (B) on Animal Resources.

3. Professor M.L. Mathur, Professor of Mechanical Engineering and Dean of the Engineering Faculty, Jodhpur University, as Chairman of Section (C) on Physical and Power Resources.

4. Professor R.P. Sinha, Professor of Mining Engineering at the Jodhpur University, as the Chaiman of Section (D) on Mineral and Industrial Resources.

5. Dr. B.B. Roy, Head of the Division of Basic Resources Studies, Central Arid Zone Research Institute, Jodhpur, as the Chairman of Section (E) on Geology, Soils, Geography and Climate.

Along with the Symposium we are also holding an Exhibition on the Natural Resources of Rajasthan. I invite all of you to see the Exhibition. The object of the Exhibition is to display, as far as possible, the natural resources of the State. It will be open to the public. For the benefit to the students of the University, it will remain open from 23rd October to 2nd November so that, on return from the mid-term vacation, they may have the opportunity of seeing it.

Impact of Science and Technology

I would like to say a few words about our general approach to problems of developmental growth. There is a universal desire in the country, and this is repeated from a thousand platforms, that we wish to raise the standard of living of our people and that everything that we are doing today by way of investments, planning and so on leads to this goal. It is generally felt that in the first few years of the Independence our progress was heartening but that in the last few years we have come more or less to a standstill. What is worse, according to some figures we have started sliding back at a rather alarming rate and that

the gap between the developed nations such as Europe, North America and Russia on the one hand, and the underdeveloped nations such as India and the whole of the Asia (except Japan), on the other, is widening at a frightening pace. In fact, some experts have even started doubting whether we will ever catch up. Others have gone to the length of saying that these countries have been born to hunger and that there is no hope of their being well fed in the near future. Still others angrily contradict this dreadful claim and assert that during the next three years we will be self-sufficient, and in support statistics of crop production, irrigation projects and so on are quoted. The fact is that the picture is not a rosy one and we have been fed so much on statistics that the idea of being given some more is not now palatable.

Then take the case of disease. Through-our own fine efforts and with the cooperation of the World Health Organization we had almost controlled malaria, that dreadful disease which causes suffering and death to millions of people and economic loss worth millions of rupees every year. But malaria is again cropping up and if we do not look sharp we may have it on a large scale amongst us. Mosquito control operations, which were a major feature in the control of malaria, are virtually at a standstill.

We have failed to eradicate such eradicable diseases as small pox, cholera and typhoid. Twenty years of independence have not taught us even the elementary rules of hygiene. You have only to take a walk in the early morning in the city of Jodhpur, or, for that matter, of any city in Rajasthan, to discover how horrible the sanitary conditions are and, therefore, there is no wonder that diseases like typhoid are permanent guests with us.

We often speak of our enlightened and scientific past and that 2000 years ago we had eminent physicians, surgeons, astronomers, mathematicians, and so on. But to talk of this past in the present difficult context is in my opinion like taking opium to get relief from an acute pain for which there appears to be no immediate remedy in sight.

What then is the remedy ? In all conscience, the problem is a complex one. It is bound up with many factors such as political stability, enlightened leadership, a disciplined and hard working people, adequate financial resources, an honest and energetic administration, and, finally, science and technology.

I am concerned today mainly with the last. No one seems to deny that our future rests largely on the application of science and technology to our daily problems. With due respect to men of religion

and philosophy, it has to be admitted that there is no aspect of human activity today which is divorced from intimate relationship with the discoveries of science and technology and their applications.

The late Prime Minister Jawahar Lal Nehru was an ardent advocate of the role of science in daily life and took every opportunity that came to him to emphasize this point. You will recall that he attended almost every session of the Indian Science Congress during his long primeministership, sometimes even at great personal inconvenience. At one meeting of the Science Congress where the arrangements were not efficient, he complained that people had taken his presence at the Congress for granted. He personally took initiative in guiding the Council of Scientific and Industrial Research and the Atomic Energy Commission. The pace of scientific development in the country is due largely to his inspiration.

Today we spend more than 20 times the sum on science which we did at the beginning of Independence. Even this sum is really insignificant when we compare it with what other countries such as the U.S.A. and the U.S.S.R., where science has made phenomenal strides, are spending. We spend barely 0.34 per cent of our national income on scientific research while the minimum figure recommended by the UNESCO is 3 per cent. Russia has well over 50 thousand geologists whereas we have barely a thousand. The tragedy of our present development is that while the Centre has poured money in science, with good results here and there, there is still a fundamental lack of the scientific temper. The States, with few exceptions, have lagged behind.

In Rajasthan, the enlightened Chief Minister, has done great things for the development of education. I hope he will now give his helping hand to the development of science in the State, because this will have a direct impact on the development of the State. In this regard I venture to make a few suggestions :

(i) There is an urgent need for a survey of the natural resources of the State in a coordinated manner. For this purpose it is not necessary to entirely depend on the Central agencies. The State should be in a position to have its own agencies for surveys of the fauna, flora, medicinal plants, forest wealth, minerals, etc. Coordination with the Central agencies will of course be necessary. The existing State agencies are too few and too ill equipped to have much impact.

(ii) It would be useful to have for the State a Science Coordination Body which will also evolve a scientific policy for the State.

(iii) In the processes both of the natural resources survey and of science coordination, the existing talent in the universities, colleges

and other institutions of learning could be harnessed and made use of. The problem will be mainly one of coordination rather than of creation of new departments.

(iv) The State should encourage private scientific societies. The least it could do is to have a Science Academy which would serve the dual purpose of encouraging science as well as giving independent advice to the Government on matters of scientific importance. At present we have a small private academy started nearly 20 years ago and known as the Rajasthan Academy of Science, with headquarters at Pilani, and of which I have the honour to be a Fellow and a former President. Within its limited resources, the Academy is doing useful work but its progress is handicapped by want of money. With Government help, one large science academy should be formed. It can serve as a centre not only for scientific meetings but also publish a good scientific journal of a high standard.

At present, as far as I am aware, the investment of the State in scientific research is extremely inadequate. It has to be realised, and this is a point which is often ignored, that scientific research is not cheap. The scientific way is long, uphill, back-breaking, expensive and paved often with disappointments and frustrations, but in the end the goal is reached. It is this aspect which is often overlooked by our statesmen and administrators. They expect quick and attractive results without much investment. When these are not forthcoming, they ridicule science and scientists and assert that money spent on science is so much waste.

In India it is customary and indeed fashionable to accuse scientists, both in the universities as well as in the research institutions, national laboratories, the various scientific survey departments, etc., as living in ivory towers and not realising the needs of the people. This is an accusation which is completely unjustified. The fact is that the problems are seldom posed to the scientists and the scientists are not taken into sufficient confidence. When the problems *are* posed, scientists have risen to the occasion.

The process of scientific research and technological invention is a difficult one. It involves observations of facts and the formulation of generalizations or the ories, both processes requiring high qualities of mind. It is common knowledge that quite often we see a thing as we want to see it and not as it actually is. Scientific observation requires the acquisition of vast knowledge as well as training in the art of observation and objectivity in respect of truth. The formulation of a generalization is not always the result of a process of neat reasoning.

Often it is one preceded by a stage of muddled imaginative suspense. Here we conjure up an attractive theory, but there is an inconvenient fact staring us in the face with a wicked. cynical smile, spoiling our beautiful picture. This may last for months or a year and sometimes you are obliged to throw away your beautiful picture into the dust bin. Sometimes, however, more new facts come to light and adjust the inconvenient facts into their places and the theory is upheld, to your great joy.

The present severe famine in the State should make us think. This is not the first time that we are having a famine. Had enongh and vigorous scientific efforts being made in the last twenty years, I am confident that by now the famine conditions would have been very much milder and perhaps only of marginal significance. We have enormous resources of underground water and it is technologically easy to tap them. Why have we not done this so far is a point which I am unable to understand. Something is lacking somewhere and we should try to find out how this lacuna can be filled. I am sure the solution will lie in the application of science.

ACKNOWLEDGEMENTS

Finally, it is a pleasant duty to express my sincere thanks and gratitude, on behalf of the University and on my own behalf, to all those who have taken part in the preparation of the Symposium. Without their assistance the Symposium would not have been possible. The members of the various Committees and the Conveners have done fine work. I would like to mention here the names of the Conveners and would request them to convey our thanks to all the members of their Committees. The Conveners are :

Exhibition Committee	:	Shri A.K. Sen; and later on Dr. Ishwar Prakash
Lodging and Boarding Committee	:	Shri K.N. Mehra
Reception Committee	:	Dr. S. Khera
Programme Committee	:	Dr. G.C. Shivhare
Publication Committee	:	Shri Jagdish Chandra
Finance Committee	:	Shri G.R. Nigam
Transport Committee	:	Dr. G.L. Gupta

In the first few months Professor K.M. Gupta did fine preparatory work as the General Secretary. Later, on his resignation due to personal reasons, the work has been taken up by Professor S.D. Misra. To both of them, and to their energetic Assistant General Secretary, Dr. D.N.

Sen, I would like to convey my appreciation and thanks.

To the members of the Executive Committee I wish to express my thanks for the continued help and cooperation.

To the student volunteers who have done fine work in receiving the delegates and in looking after their comforts, I wish to say a special word of thanks.

To the members of the General Organizing Committee I am grateful for their cooperation.

The University Grants Commission and the University of Jodhpur have given generous donations which have made the holding of the Symposium possible and we express our indebtedness to these august bodies.

The following business firms of Jodhpur gave generous donations towards the publication of our brochure and we thank them heartily :

The Arun Hotel; The Light House; The Shah Theatres Private Limited; and The West Airlines.

Finally, I hope, Ladies and Gentlemen, that you will join me in wishing success to this unique Symposium. Apart from the delegates who will read the papers, I invite all of you to feel free to attend any of the sessional meeting in which you may be interested.

2. REPORT OF THE GENERAL SECRETARY

To the Symposium and Exhibition on Natural Resources of Rajasthan held at the Jodhpur University, Jodhpur, on 23–26 October, 1966

By

S. D. MISRA

Professor of Zoology, Jodhpur University, Jodhpur

THE SYMPOSIUM

The Symposium on the Natural Resources of Rajasthan was organized by the University of Jodhpur from 23 to 26 October, 1968, in which 117 papers were presented, representing 46 research institutes, government departments and universities, including three foreign institutions. The deliberations covered the resources in five sections, viz., (A) Plant Resources, (B) Animal Resources, (C) Physical and Power Resources, (D) Mineral and Industrial Resources, and (E) Geology, Soils, Geography and Climate of Rajasthan. The vast informative material on the natural resources of Rajasthan, now collected, will be available to the planners for the all-round development of the State *on a scientific basis. The papers are printed in full in* Part 2 *of this* book.

THE EXHIBITION

The Exhibition organized on the occasion of the Symposium on Natural Resources of Rajasthan covered the same sections as the Symposium, but lasted for seven days more than the Symposium to give an opportunity to the citizens of Jodhpur and the students of the *University to have a glimpse of the resources and potentialities of the* State.

Nineteen research institutes and the State as well as Central Government organizations, corporations and industries have sent their *exhibits for display.*

LIST OF PARTICIPANTS IN THE EXHIBITION

1. Central Arid Zone Research Institute, Jodhpur.

2. Botanical Survey of India.
3. Botany Department, University of Jodhpur.
4. Forest Department, Government of Rajasthan.
5. Zoological Survey of India.
6. Zoology Department, University of Jodhpur.
7. Anti-Locust Station (Government of India), Jodhpur.
8. Hindustan Zinc Ltd., Udaipur.
9. Hindustan Salts Ltd.
10. Atomic Energy, Kota.
11. Geological Survey of India.
12. Indian Meteorological Department.
13. Geography Department, University of Jodhpur.
14. Engineering Faculty, University of Jodhpur.
15. Geology and Mines Department, Government of Rajasthan.
16. Fertilizer Corporation of India.
17. Public Relations Office, Rajasthan Government, Jodhpur.
18. United States Information Service, New Delhi.
19. Food and Agricultural Organization of the U.N., New Delhi.

3. RESOLUTIONS

Resolutions Passed at the Concluding Plenary Sesssion

of

The Symposium on Natural Resources of Rajasthan,
Held at Jodhpur on 23-26 October, 1968

The following resolutions were passed unanimously at the Concluding Plenary Session of the Symposium on Natural Resources of Rajasthan held at the Jodhpur University, Jodhpur, on 26 October, 1968 at 2 P.M. :

Resolution 1

Surveys of Natural Resources

RESOLVED

To recommend to the Government of Rajasthan that there is an urgent need for co-ordinated and comprehensive scientific surveys of all the natural resources of Rajasthan in order to ensure rapid development based on science and technology. For this purpose, while co-ordination with the Central agencies is of course desirable, it is highly necessary that the State should have its own agencies for the scientific surveys of the flora, fauna, medicinal plants, grassland and forest wealth, geology, minerals, etc., preferably in an integrated manner. The existing State agencies are too few and too ill equipped to have much impact.

Resolution 3

Academy of Science and Technology

RESOLVED

To recommend to the Government of Rajasthan that it should encourage the establishment of private scientific societies by giving liberal financial and other grants.

FURTHER RESOLVED

That in the first instance the State should initiate and help in the establishment of an Academy of Science and Technology for Rajasthan, covering all scientific subjects and to be run as a private society which would further foster the advancement of science in all aspects, including scientific deliberations and the establishment of scientific standards, start a scientific journal of high standard and advise the State Government on matters of scientific and technological policy.

Resolution 4

Floral Composition of Rajasthan

WHEREAS

(a) Some handy publications giving account of the important resources of the State are essential for plant-based studies and programmes;

(b) The publication of detailed flora of the entire State of Rajasthan may take a long time;

(c) Recent intensive field work in Rajasthan by botanists, agrostologists, etc., has brought to light numerous ambiguities and difficulties in the correct determination of important or common plants of Rajasthan;

(d) The correct identity of these plants is essential for the description of plant communities, forest types and in the utilization of these natural resources;

(e) There are large tribal populations in the State and there is little information on the plants used by them for food, medicine, etc.;

(f) The folklore, when subjected to scientific scrutiny, analysis and experimentation, has in several cases yielded valuable material for the exploitation of natural resources;

(g) The plant resources are being continuously abused for the supply of food, fodder, fuel, etc., thereby resulting in the loss of plant wealth of the State;

RESOLVED THAT

(1) The writing up of a forest flora of Rajasthan be taken up by the State Forest Department in collaboration with the Botanical Survey of India and other competent agencies.

(2) The preparation of an illustrated ecological account of the grasses of the arid parts of Rajasthan be taken up in collaboration with the Central Arid Zone Research Institute, Jodhpur, the Indian Grassland and Fodder Research Institute, Jhansi, the Botanical Survey of India, Calcutta, and the various universities in the State.

(3) The programme of writing a detailed flora of Rajasthan be taken up by the Jodhpur University.

(4) Taxonomists and biosystematists doing monographic work may give priority to species of economic importance such as grasses, genera of importance to forestry and genera of other economic plants such as plants yielding fibres, tannins, etc.

(5) The botany departments of the various Universities in the State may make efforts to study the use of plants for food, fibre, medicine, etc. as a subject under economic botany, while the problems related to the development of techniques of exploitation of these plant species for their raw material may be taken up by research institutes.

(6) Measures be taken to establish preservation reserves in different vegetation types with a view to preserve and study the endangered, rare and economic plants, both indigenous and exotic, found in the State.

Resolution 5

Plants Useful to Man

WHEREAS

(a) The economy of western Rajasthan is primarily dependent upon grasslands which are progressively shrinking in area due to the 'Grow More Food Campaign' and are over-exploited;

(b) Much remains to be done in the determination of production potential of the different grasslands under different methods of management :

RESOLVED THAT

(1) The State Government be approached for formulating a 'Grassland and Grazing Policy', somewhat similar to the 'National Forest Policy', for effective conservation, improvement and management of grassland resources of the State.

(2) A more connected and correlated study, on the basis of ecosystems, primary and secondary productivity and energetics, be undertaken on natural ecosystems for the proper evaluation of management practices.

Resolution 6

Physiology and Biochemistry of Plants

RESOLVED THAT

The study of the physiology and biochemistry of plants of economic value to Rajasthan be undertaken by the local universities and other institutes with special reference to water relation, germination, proteins, fats, fibres, carbohydrates and alkaloid contents of the crop, fodder and medicinal plants.

Resolution 7

Animal Resourses of Rajasthan

WHEREAS

(a) Lacunae exist in our knowledge of Rajasthan fauna of parasitic protozoa, earthworms, Turbellaria, parasitic helminths (particularly monogenetic Trematoda), ticks and mites, Myriapoda, Crustacea and insects like Mallophaga and Collembola;

(b) The fauna of Rajasthan termites has been worked out in sufficient detail, but the biology, behaviour, physiology, ecology and social habits of Rajasthan termites have not been touched; on the other hand, whereas the biology of Rajasthan rodents has been worked out in sufficient detail at the Central Arid Zone Research Institute, Jodhpur, sufficient awarness of their control is lacking and has assumed great importance in relation to saving our food grains from them;

(c) The development of plant nematology in the State has shown promise;

(d) The work on the high and low-potassium-in-blood types of sheep (HK and LK) at the Central Arid Zone Research Institute, Jodhpur, has aroused the hope of developing an 'Indian Merino' by selective breeding of the two local types.

(e) Rajasthan, fortunately, is still rich in its wild life fauna and there is time to preserve it :

RESOLVED THAT

(f) Monographic works, in order of the economic importance of the groups, be undertaken on parasitic protozoa, earthworms, Turbel-

laria, parasitic helminths (particularly monogenetic tramatodes), ticks and mites, Myriapoda, Crustacea and insects at the various universities and research institutes of the State and the Desert Regional Station of the Zoological Survey of India, and wherever facilities for this work exist.

(2) Biology, behaviour, physiology, ecology and social habits of Rajasthan termites be undertaken at the various universities of the State.

(3) For controlling the rodents, arrangements be made to hold regular training courses, preferably at the Central Arid Zone Research Institute, Jodhpur, where facilities for such a training are available.

(4) Regular cropwise surveys should be held in a co-ordinated manner throughout the State, correlating the incidence of nematodes and other pests with climatic conditions, soil types and external symptoms.

(5) Detailed genetic experiments be undertaken on the low-potassium and high-potassium-in-blood types of sheep at the Government farms or at the Central Arid Zone Research Institute, Jodhpur, where such work has been initiated to develop a stock of sheep rich for its wool quality and another stock rich for its mutton.

(6) A census of the wildlife fauna of the State be undertaken and a sanctury be established, particularly for the Great Indian Bustard which is threatened with extinction.

(7) Secondary potentials (both terrestrial and freshwater) of Rajasthan need to be studied at the various universities and other research institutes of the State with the help of tracer technique, in order to understand the energy flow and cycling of materials at various trophic levels.

Resolution 8

Solar and Wind Energy

WHEREAS

(a) Considering the importance of solar energy and the existing need for obtaining information on the subject particularly on the following points :

(i) Working knowledge of earth's relationship to the sun for calculating direct radiations; (ii) solar radiation intensity and its measurement; (iii) sky diffusion radiation and radiation from the surroundings; (iv) solar radiation properties of materials; (v) thermal effects of solar radiation and know-how to control and utilize it; and

(vi) sun path diagrams for the latitudes spanning Rajasthan.

(b) The development of wind power, for meeting the future power demands of the State, must harness the wind energy economically with the help of locally available material and technology.

RESOLVED THAT

(1) A Solar Laboratory be established in Rajasthan to collect and prepare solar diagrams for the region, and where necessary to carry out research work on the design and utilization of solar appliances and equipment.

(2) A Wind Power Research Station be established in Rajasthan, if necessary with the help and co-operation of the University Grants Commission and the State and Central Governments, to meet the future power demands of the State.

Resolution 9

Surface and Ground Water

WHEREAS

Water is one of the greatest limiting factors for the development of Rajasthan and for the exploitation of surface and ground water, the construction of dams and the provision of low-cost pumps are the principal problems :

RESOLVED THAT

(1) The development of water resources should be on the following lines :

(i) Intensive hydrological investigations on selected basins be carried out to evaluate the surface and ground water yield and the effects of various operating factors; (ii) systematic ground water exploration, assessment and exploitation be carried out on the basis of basins rather than on arbitrary political boundaries; (iii) the number of meterological stations in the State be increased for proper assessment of water resources; (iv) the behaviour of ground water bodies be studied in relation to precipitation and surface water resources; (v) the ground water for irrigation should work out in cost equitable to canal water; (vi) the ground water exploitation project should be long-lasting, taking into account the discharge and recharge and thus ensuring that the resources do not dry up.

(2) The construction of dams should give special consideration to petrofibres of the rocks.

Resolution 10

Minerals, including Atomic Minerals

WHEREAS

(a) It has been found that the State is rich in mineral resources and there is need of some agency which would process these at low cost to encourage their wide-scale discovery and utilization;

(b) From the Symposium discussions it has emerged that sizeable deposits of base metals have been located by the Geological Survey of India and other agencies, but there is a serious time-lag and short-fall in the exploitation of these deposits and the smelting of ores to metallic stage, resulting in avoidable large imports of these commodities involving heavy drain on our foreign exchange;

(c) Resources of all the necessary raw material for ceramic industry, except coal, are available in Rajasthan, and most of these are being exported to the neihbouring States while there is a growing demand for various types of ceramic ware in the State.

(d) The pegmatite-base atomic mineral deposits like beryl, etc., are limited in extent and their occurrence is highly erratic, and it has been found that the Mineral Concession Rules and their interpretation by the State Government tend to discourage their exploration, resulting in serious decline of their output;

(e) From the Symposium discussions it has emerged that there is need to encourage setting up of industries based on industrial minerals like barytes, asbestos, mica, fluorite, etc., of which there are rich deposits in the State;

(f) The country is importing almost all its requirement of potash, and the demand for this mineral is likely to increase rapidly for use in fertilizer manufacture, and Rajasthan has a fairly good chance of finding out potash deposits in evaporite basins which will require many types of techniques, including deep drilling, gamma-ray logging, etc., employed by the Oil and Natural Gas Commission and other organizations for oil :

RESOLVED THAT

(1) A branch of the Ore Dressing Section of the National Metallurgical Laboratory (Council of Scientific and Industrial Research) be set up at a suitable location in Rajasthan for carrying out tests on benficiation and upgrading of low-grade ores and industrial minerals, the charges for which may be fixed at a nominal rate to encourage wide-scale discovery and utilization of minerals.

(2) The State Government may take urgent steps to expedite the mining of the deposits, fixing realistic targets so that the heavy drainage on foreign exchange in the import of these commodities is gradually reduced and eventually stopped.

FURTHER RESOLVED THAT

The remaining deposits of zinc in the State be brought on the economic production stage soon and for this the import of concentrates for the second smelter be undertaken.

(3) The State Government be urged to take necessary steps and give encouragement for setting up the ceramic industry in the public or private sector.

(4) The State Government be urged to liberalize their interpretation of Mineral Concession Rules for the pegmatite-based atomic minerals in view of their deposits being limited in extent and their occurrence being highly erratic.

(5) The State Government be urged to encourage industries based on industrial minerals like barytes, asbestos, mica, fluorite, etc., and even subsidize them in the initial stages.

(6) That a Committee on Potash be formed with representatives of organizations like the Geological Survey of India, Oil and Natural Gas Commission, Fertilizer Corporation of India, Directorate of Mines and Geology of Rajasthan, and Department of Atomic Energy. Further resolved that the work of this Committee be to coordinate the work and draw out overall programmes for potash exploration in the State and in the country and follow the programme of exploration and to advise the Government on potash exploration.

(7) A similar Committee be formed for nickel and cobalt also.

Resolution 11

Physiography

WHEREAS

Aerial photographs are an essential tool for quick and accurate surveys of natural resources like the geomorphological, soil and vegetation surveys :

RESOLVED THAT

In the interest of research work and development plans, aerial photographs of Rajasthan be made available to research institutes and universities.

4. EXECUTIVE COMMITTEE

OF THE SYMPOSIUM

General President

DR. M.L. ROONWAL
Vice-Chancellor, University of Jodhpur

General Secretary

PROF. K.M. GUPTA [LATER PROF. S.D. MISRA]

Members

1. DR. MUKHTAR SINGH, Chairman Section A
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4. PROF. R.P. SINHA, Chairman Section D
5. DR. B.B. ROY, Chairman Section E
6. DR. G.C. TANEJA, Central Arid Zone Research Institute, Jodhpur
7. GROUP CAPTAIN P. J. MATHEWS, Manager, Oil and Natural Gas Commission, Jodhpur

SYMPOSIUM ON THE NATURAL RESOURCES OF RAJASTHAN

Jodhpur University, Jodhpur, October 1968

The Participants : Left to Right

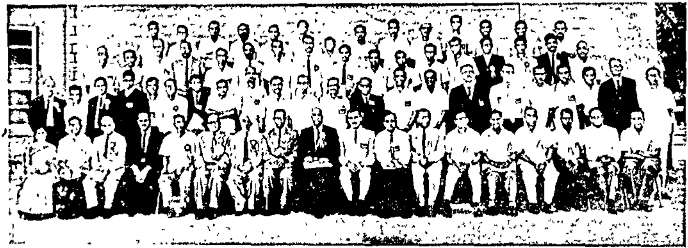
First row (sitting) : Dr. (Miss) Kamal Mohnot, G.R. Nigam, Dr. M.L. Mathur (Chairman, Section C), Group Capt. P.J. Mathews, Dr. B.B. Roy (Chairman, Section E), Dr R.P. Sinha (Chairman, Section D), Dr. Mukhtar Singh (Chairman, Section A), Dr S D. Misra (General Secretary & Chairman, Section B), Dr. M L. Roonwal (Vice-Chancellor and General President), Dr S D. Tewfik (Chief, UNESCO Mission to India), Dr. S Khera, Dr. G.C. Shivahare, Jagdish Chandra, Dr. G.L. Gupta, K N. Mehra, Dr. Ishwar Prakash, Dr. K.M. Gupta and G C. Mishra.

Second row : K R. Bhatia, R P Jolly, Dr. A.K. Tewari, Shyam Bhandari, A. Krishnan, Dr. R K Gupta, Dr G S. Roonwal, I.C. Gupta, Dr. M.N. Tewari, O N. Kaul, R.N. Kaul, Dr. S C Pandeya, Dr. S.K. Jain, C S. Raja Rao, V D. Mahajan, Dr. R.D. Barner, Dr. George R. Gist, O.P. Vaish, H K. Vyas, O P. Bohra, K.L Bhola and Dr A.N. Lahiri.

Third row : Dr N. Prasad, Bimal Ghose, Dr. J.J. Nossin, Dr. J K. Maheshwari, N L. Kachhara, P.D. Nanda, Suresh Pandey, M.H. Qureshi, P.R. Rakhecha, Jagdish Chandra, Dr H.S. Nama, S.M. Mohnot, N D Joshi, M.K. Mathur, Dr. B.S. Sankhla, S.N. Sharma and K. Narasimhachary.

Fourth row : S. Kathju, D D Chawan, Dr. N. Sankhla, Dr. M.M. Bhandari, Dr. K V. Paliwal, B.L. Mathur, M Hasan, Dr. P D. Gupta, Wasi Ullah, P.C. Chatterji, Dr. G.C. Bhatnagar, M G. Tikyani, R.R. Prasad and T.P. Verma.

Nat. Resources, Rajasthan : The Participants To face page 22 PLATE 1



PART 2

Scientific Papers

SECTION A

Plant Resources of Rajasthan

1. Floral composition of Rajasthan
2. Plants useful to man
   (a) Crops and grasses
   (b) Forest resources
   (c) Plant products
3. Physiology of plants
   (a) Germination studies
   (b) Water relations

Chairman DR. MUKHTAR SINGH
Recorder DR. M.N. TEWARI

Chairman's Address

DEVELOPMENT OF MAJOR PLANT RESOURCES IN RAJASTHAN

By

MUKHTAR SINGH*

Director, Central Arid Zone Research Institute, Jodhpur

Plant resources are of undoubted significance in the welfare and the economy of the State, as in any part of the world. Food, fodder, fuel and fibre are the four basic needs which plants supply. Plants are also important sources of industrial and medicinal products. It is, therefore, in the fitness of things that this subject has been assigned an important place in this Symposium on Natural Resources. A large number of papers has been contributed for the Section. These cover the different aspects of the plant resources, viz. (1) floral composition, (2) studies on useful plants, including grasses and forest trees and plant products, (3) plant physiological studies with reference to germination, plant-water relations and drought resistance, and (4) plant diseases. Surprisingly, although crops are grown on about 40 per cent of the land, cropping patterns and crop production have not been directly discussed in any of the papers. It would, therefore, be appropriate if I touch on this aspect, too, in my address, in addition to the others.

It must be stated at the outset that plant resources cannot be considered in isolation from the environmental factors. Kind of vegetation, its survival, distribution and productivity are all greatly influenced by the environmental complex consisting of climate, soil, topography, irrigation and socio-economic conditions. Rajasthan represents diverse conditions of environment, some of which are peculiar to this State, as distinct from the other parts of the country. Krishnan (1968) has described the climatic pattern in Rajasthan on the basis of the system of classification of Thornthwaite. Except Mount Abu which is humid, and Jhalawar and Banswara districts which are sub-humid, the remaining part of the State falls under the arid and semi-arid zones.

**Present address* : Director, Potato Research Institute, Simla

Chairman's Address

DEVELOPMENT OF MAJOR PLANT RESOURCES IN RAJASTHAN

By

MUKHTAR SINGH*

Director, Central Arid Zone Research Institute, Jodhpur

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**Present address* : Director, Potato Research Institute, Simla

The boundry between arid and semi-arid zones intersects Jalore and Pali districts, goes along the boundry of Ajmer and Nagore and then passes through Sikar and Jhunjhunu districts.

Aravallis are the dividing range between the relatively wetter and the drier parts. The region to the west of this range represents desertic conditions with low rainfall which decreases from about 500 mm at the foot of the Aravallis to as low as 100 mm in the Western parts. About 90 to 95 per cent of the entire rainfall is received in the short period of July to September. This cannot be considered as a disadvantage as it makes seasonal vegetation possible, but it is the erratic distribution of rainfall even within the rainy season which plays havoc, more particularly in certain years over greater part of the State.

A wide range of soils occur in the State. These have been classified into 12 groups by Mehta (1968). Roy and Sen (1968) have classified the soils into (1) desert soils, (2) sand-dunes, (3) red desertic, (4) old alluvium, (5) recent alluvium, (6) sierozems, (7) red and yellow, (8) brown, (9) yellowish-brown, (10) red loam, (11) black, (12) saline soils of depressions, and (13) lithosols and regosols of the hilly terrain.

In many parts of the arid zone, sandy texture of the soil and the presence of a hard calcium carbonate layer, accentuate the conditions of drought.

Because of high evapo-transpiration, low rainfall, and droughty soils, the needs of the State (particularly Western Rajasthan) for irrigation are indeed great. The irrigated area is, however, only about 15 per cent of the cultivated area. Ground water in many cases is available only at great depths and is, not infrequently, brackish.

It is against this background of environmental factors that the plant resources of the State have to be considered. Such consideration should logically begin with the land-use pattern.

The proportion of cropped area to total land in Rajasthan is lower than in India. This is to be expected, as relatively more area is occupied by marginal and sub-marginal land. Notwithstanding this, the forests partake only a small share. Permanent pastures and grazing land, culturable waste and fallowing claim greater proportion of the land. This may give the misleading impression that the State is better off in the matter of forage resources.

The livestock pressure is high, particularly because the carrying capacity of most of the grasslands is low. The livestock do utilise the

sparse vegetation on culturable wastelands and other fallow fields, but this too is inadequate in amount and poor in quality. Overgrazing and absence of sound practices of grassland management have led to denudation, and replacement of superior grasses by inferior ones and weeds.

Conditions within the State are not uniform. There are large regional variations and these must be reckoned with for the development of plant resources on a scientific basis. Regular forests are practically non-existent in some regions and very low in others. Large areas of uncultivated land are available in almost all the regions but these are hardly developed for planned forage production and utilization.

The question immediately arises whether there is any scope for readjustment among different kinds of land use or they are properly balanced. The answer to this question would depend on the preparation of balance sheets between the availability and requirements in regard to major needs of the human and livestock population, taking into consideration the potentialities and limitations of each region. This will require a deep and penetrating study. Some observations could, however, be made on the basis of general consideration and available data.

Once deficit, the State is now exporting food grains and vegetables (Kala, 1964). The surplus is contributed by the production in the areas receiving irrigation and/or higher rainfall. The use of high-yielding and fertilizer-responsive varieties of crops and inputs of complementary factors will help in further increases in the crop production in these areas. Expansion of irrigation facilities will, in due course, justifiably increase the cropped area, particularly in the districts receiving low rainfall. There is, however no scope or justification for the increase in the area under crops in the non-irrigated areas, particularly in the arid zone, even though they may be deficit in crop production. The extension of area under food grains to marginal and sub-marginal lands unsuitable for food production merely leads to instability with dire consequences for the future (Sen, 1967). In fact the area under grasses, in particular, and forests, as far as possible, should increase to meet the needs of fodder and fuel, which are bulky commodities and are expensive to be transported, in years of drought. More area under grasses will also provide the much needed protection against erosion. Of particular interest in this regard is the technique of wind strip cropping which has been tried at the Central Arid Zone Research Institute, Jodhpur.

The total area under forests in the State falls short of the figure prescribed in the National Forest Policy of India. In regions where the environment is favourable for raising successful plantations of economically important fast-growing tree species, the area under forest need to be increased. Here a combination of grasses and forest trees would appear to be feasible. In the arid region, environment is not hospitable for production forestry. Nevertheless, as pointed out by Kaul (1963), there is definite need here for protective tree planting, at suitable niches, viz. afforestation of shifting sand dunes to portect the habitation, lines of communication and fertile agricultural fields; raising shelterbelts or windbreaks around fields to reduce evapo-transpiration and on *nadis* and tanks to reduce evaporation losses from free water surface; establishment of road-side avenues for shade and shelter; and planting of top feed tree species in range lands for providing shade, shelter and nutritious leaf forage to grazing animals—especially during periods of scarcity.

Apart from the need and scope for adjustment in the major land use pattern, the problems and prospects of developing plant resources within each kind of land-use merit consideration.

Cropping patterns and relative yields of crops differ in the different regions. These could largely be interpreted in terms of rainfall, irrigation and soil type. *Kharif* crops such as *bajra* and pulses, predominate in the non-irrigated parts of western Rajasthan. In Ganganagar, where irrigation water is available for part of the area, rabi crops (gram and wheat) are grown in addition to cotton, *bajra* and pulses in *Kharif*. Gram and wheat, and to some extent linseed and *jowar* are also important crops on moisture-retentive fine-textured soils in south-eastern region. Cultivation of maize on upland and rice on low land, with opposing water requirements, examplifies the role of topography in influencing choice of crop in Dungarpur and Banswara. Rape and mustared are grown principally on alluvial soils in Alwar and Bharatpur districts. Sesamum is cultivated in some of the regions, under conditions of varying soil and rainfall.

Major changes in corpping are possible only with irrigation. For example potatoes and sugar beet, and ground-nut may claim fair acreage on coarse-textured irrigated soils. There is, however, considerable scope for improving yields which are low or medium in many crops by introducing improved varieties and technology under irrigated and non-irrigated conditions.

The low yield of *bajra* in western Rajasthan is because of the coarse-textured soil and drought to which the crop is subject. There are attractive possibilities of replacing the existing variety of *bajra* by a suitable dwarf early-maturing variety which can escape the drought. There is evidence to show that *Kharif* pulses such as *moong*, *guar* and *moth* have lower consumptive use than *bajra* (Lahiri, 1968). Deeper root system of pulse crops is also expected to help them to tide over short period of drought. There is urgent need to select early-maturing drought-evading or drought resistent varieties of crops such as *bajra*, *jowar*, *moong*, *guar*, sesame and castor, grown in arid zone. The Plant Introduction unit of the Indian Agricultural Research Institute, New Delhi, is working at the Central Arid Zone Research Institute, Jodhpur, to screen large collections of the crops of the zone for their suitability for introduction in the arid zone. Physiological approaches to adjust the plants to the environment may also lead to practical results. The existing knowledge on the subject is reviewed by Chinoy (1968). There are two possible approaches, viz. (1) seed treatment, and (2) the use of growth retardants. Kathju and Tewari (1968) have reported favourable response to vitamin C on water uptake and growth of *Tephrosia*. Although the effect of seed treatment on drought resistance has not been found to be consistent (Waisel, 1962), the extension of these studies to crop plants of arid zone should be rewarding. The possibilities of growth retardants which reduce the internodal length is suggested in a paper from Jodhpur University on the basis of preliminary studies. Growth retardants may prove useful in arid environment, if they retard growth by increasing root-shoot ratio without reducing photosynthesis. The possibilities of the use of anti-transpirants are also worth investigation.

As irrigation water is a scarce commodity in Rajasthan, studies on efficient use of a unit of water for crop production are important. Here again quick-growing and early varieties such as Russian barley, *Sharbati Sonora* wheat, *Hybrid jowar* would be a distinct advantage. These need to be tried.

Equally important is the need to recognise the importance of crucial or critical periods for irrigation under conditions of limited water supply. For the use of brackish irrigation waters and saline and/or alkali soils, the choice of salt-tolerant crops and varieties and proper irrigation method are important. There is considerable scope for research in this area.

It must be emphasized that cultural practices in the desert must be such as do not accentuate soil erosion. Leaving the stubbles of *bajra* at a hight of 45 cm. is found to prevent erosion by wind (Misra, 1964).

Plant protection is particularly important in Rajasthan for increasing crop yields and conserving the produce. A survey of crop diseases in Rajasthan is presented by Bilgrami and Bhatnagar (1968). Preventive and curative measures to combat these and other pests such as termites, birds and rats are necessary. Mention may be made here of a successful method of controlling desert gerbils through the use of one-shot bating with Sodium-monofluoro-acetate (Prakash, 1963).

Grasses and grasslands occupy a special place in the plant resources of economic value in the State. The grass cover here is designated as *Dichanthium - Cenchrus - Lasiurus* (Dabadghao, 1960). A number of papers contributed for the symposium deal with the subject (Pandeya, 1968; Kaul and Chakravarty, 1968; Kaul, 1968; Nanda and Gupta, 1968; Joshi, 1968). As mentioned earlier the grasslands in the State are over-grazed, denuded and deteriorated; inferior grasses, and pernicious woody and herbaceous weeds predominate. Undoubtedly, it is imperative to develop the grasslands for improving the nutrtion and productivity of the lievstock. The first step in such a programme will necessarily consist in closure, but it need hardly be stressed that mere enclosure will not deliver the goods. A well planned follow-up programme is necessary to renovate the grasslands. This is because all types of good, bad and indifferent vegetation comes up soon after closure. Thus a mixed vegetation consisting of good as well as inferior grasses, thorny bushes, and unpalatable weeds off-sets the beneficial effects of closure. Weed control measures through the use of weedicides and judicious grazing management at the appropriate time to control the annual weeds before flowering are, therefore, necessary. The weed control programme should be quickly followed by light dressings of fertilizer to improve the productivity of the grassland. In the case of denuded grassland it may also be necessary to introduce superior grasses and suitable legumes by reseeding (Kaul and Chakravarty, 1968). In the case of certain grasses planting of rooted slips are preferable for better establishment. It is not only necessary to adopt the right practice at the right time but also in the right sequence to achieve the desired results.

It is necessary that the plant species and varieties are adapted

to the environment. From an economic stand point it is not the adaptability merely for survival but for productivity which is important. Under natural conditions the principle of adaptability is examplified in the relative dominance of *Lasiurus sindicus* in relatively more arid environment as compared to *Cenchrus ciliaris* and *C. setigerus*. *Dichanthium annulatum* is mainly found in low lying depressions where water tends to accumulate or in high rainfall areas. There is, however, considerable scope for further improvement by selecting eco-types and varieties. Pandya has referred to the eco-types of *Cenchrus ciliaris* selected by him. It will be interesting to assess them for their response to different degrees of moisture stress so that the most suitable ones are multiplied and introduced for reseeding. At the Central Arid Zone Research Institute, Jodhpur, too, promsing strains of *Cenchrus ciliaris*, *C. setigerus* and *Panicum antidotale* have been selected.

Forests are also an important plant resource which need development and improvement. A detailed account of the forest types, major and minor forest produce and measures for improvement is presented by Srivastava (1968). Kaul (1968) has dealt with shelter belts and sand binders for protection. Forest products have been specially indicated in two papers (Rao and Shiva, 1968; Gupta and Saxena, 1968). Considerable work has been done at Central Arid Zone Research Institute, Jodhpur, on the techniques of raising seedlings, establishment of seedlings and selection of quick-growing tree species. The Institute has released a few promising tree species viz., *Acacia tortilis* (Kaul, 1963) and *Eucalyptus melanophloia*, *Eucalyptus tersellaris*, *Eucalyptus terminalis* and *Eucalyptus camaldulensis* (Kaul and Nambiar, 1966a) for tree planting in arid and semi-arid regions of the country. Techniques of raising tree plantations have been worked out for different land types viz., shifting sand dunes (Bhimaya *et al.*, 1961), shallow soils overlying hard calcareous pan and sandy plains (Kaul and Ganguli, 1964) and rocky and semi-rocky sites (Kaul *et al.*, 1966b). Studies on raising of shelterbelts have also been carried out and 102 km long shelterbelts have been raised at the Central Mechanised Farm, Suratgarh, (Bhimaya and Chowdhry, 1961). The problems of the zone are, however, challenging and large scale developmental projects based on the techniques evolved are necessary to make an impact.

Apart from the three major plant resources which have prior claim for development, there is a rich variety of flora, the potentialities

of which need to be exploited. Reference may be made to the review by Jain (1968) and papers by Kumar and Singh (1968) and Maheshwari (1968).

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Rest of the references are from the papers contributed for the Symposium on 'Natural Resources of Rajasthan', Jodhpur, 1968.

STUDIES ON THE ALIEN FLORA OF RAJASTHAN

By

J. K. MAHESHWARI

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I—INTRODUCTION

The flora of Rajasthan comprises several phytogeographical elements which are common to the adjoining areas of Punjab, Delhi, North Gujarat, Uttar Pradesh, Kutch, Saurashtra and Sind (Maheshwari, 1963). In contrast to the high endemic content of species in regions like the Himalayas and South India, the State is rather poor in this element.

The present study covers only such species which following their immigration or introduction during the historic and modern times have become naturalized and may now be considered as the denizens of the State.

II—FACTORS INFLUENCING NATURALIZATION AND FLORISTIC COMPOSITION

The introduction and naturalization of alien plants in the State is influenced by three groups of factors: climate, soil, and man and his associated agents. Since the post-glacial period through prehistoric and historic times, the climax evergreen vegetation over most parts of India has suffered greatly from natural causes and biotic interferences, resulting in the desiccation or desertification of the land. It is believed that during the period 5000-4000 B.C. the present desert area of Rajasthan was well-wooded and humid. Today, the total area under forests in the State is only 11 per cent of the land area. Of this, only 4 per cent is under original forests and the rest had been denuded. While camels, sheep, hare, cattle and periodic locust attacks disturb the development of vegetation in the area, no animal has been more destructive than the goats which wander to and fro, distributing the burred, prickly, hairy or adhesive seeds and fruits of various weeds and continually select and eat out the better pasture plants. The obnoxious, prickly, foul-smelling and poisonous plants are usually left untouched and in this way they are at a great advantage over palatable plants

which are being continuously grazed down. A regular feature in this area is the failure of the monsoon that has made the cattle breeders of the north-western sector to lead a nomadic life. It has been estimated that nearly 15,000 nomadic families who own about 10 lakh good breed of milch cattle have to migrate their animals to neighbouring areas in search of water and fodder. These wandering cattle cause immense damage to the vegetation and facilitate the colonization of plants adapted to changed conditions. The constant harvesting of vegetation for fuel and fodder is another important factor depleting the vegetation and favouring the invasion of weeds on exposed situations (Christian, 1959; White, 1960).

The modes of behaviour of introduced plants in a new environment are extremely diverse as well as unpredictable. The most important factor helping the naturalization of adventive plants, besides soil, climate and possibly trace elements, is that they arrived in this country leaving behind all the parasites and natural enemies (e.g. fungi, birds, mammals and insects) that limited their extension in original homes. As a result such plants have proliferated rapidly and set up competition with the indigenes. The mesquite (*Prosopis juliflora* DC.) in Rajasthan and Sudan, *Lantana* in India, prickly pears (*Opuntia)* in Australia and India, and the water hyacinth (*Eichhornia crassipes* (Mart.) Solms) in South-East Asia, the Congo and the Nile are some of the well known cases (Maheshwari, 1962).

In Rajasthan Desert the competition between plants of the same or of different species is not discernible on account of plenty of vacant space in the region and the formations being generally of the open type. In many cases the exotic species have found themselves in very congenial surroundings and are able to compete with the native plants. The mesquite (*Prosopis juliflora* DC.) of the arid regions of Mexico and Central America is one such plant. Today, it has become a pest and the people dread it, since it inhibits other plant growth. It is also threatening to exterminate an indigenous species, namely *P. cineraria* (L.) Macbr. (syn. *P. spicigera* L.) on account of its fast growth on arid barren grounds and survival under vicious grazing by goats (White, 1960).

The introduction of foreign plants has also wrought a change in the faces of the vegetation. Thus, mixed plant communities composed of an amalgam of indigenous and adventive elements and pure associations

of adventive plants (e.g. *Argemone mexicana* L.) are seen in the flora. Among the adventive species that have gone into the composition of various communities and associations may be mentioned *Lantana camara* var. *aculeata* Mold., *Opuntia dillenii* Haw., *Prosopis juliflora* DC., *P. glandulosa* Torr., *Cryptostegia grandiflora* R.Br., *Annona squamosa* L., *Argemone mexicana* L., and *Eichhornia crassipes* (Mart.) Solms.

III—FLORAL ELEMENTS

It is interesting to note that a large number of floral elements is represented in the State. Blatter and Hallberg (1920), besides others, recognized three distinct elements in the flora of Rajasthan, namely a western, an eastern and a more general element (including Indian element). A further analysis of the flora reveals that seventeen types of floral elements can be distinguished. These may be grouped into five main classes as follows (see also Eig, 1931; Maheshwari, 1960, 1962; Bharucha & Meher-Homji, 1965; Meher-Homji, 1965) :

1. Endemic Element

Melhania magnifolia Blatt. & Hall., *Pulicaria rajputanae* Blatt. & Hall., *Convolvulus densiflorus* Blatt. & Hall., and *Euphorbia jodhpurensis* Blatt. & Hall.

2. Indian Element

Maerua arenaria (DC.) H.f. & T., *Rhus mysurensis* W. & A., *Sarcostemma acidum* Voigt, *Capparis grandis* L.f., *Anogeissus pendula* Edgew., *Tamarix dioica* Roxb., *Alysicarpus longifolius* W. & A., *Mimosa hamata* Willd., *Rivea hypocrateriformis* Choisy, and *Ipomoea sindica* Stapf.

3. Eastern Element (Indo-Malayan Element)

Capparis sepiaria L., *Dregea volubilis* Bth. ex H.f., *Leptadaenia reticulata* W. & A., *Borreria articularis* (L.f.) Williams (syn. *B. hispida* Sch.), *Adhatoda vasica* Nees, *Dendrophthoe falcata* Etting., and *Leucas aspera* Link.

4. Western Element

I. North African—Indian Desert Element or The Saharo-Sindhian Element—*Fagonia cretica* L., *Heliotropium rariflorum* Stocks, *Lycium*

barbarum L., *Oligomeris linifolia* Macbr., *Peganum harmala* L., *Seddera latifolia* Hochst. & Steud., and *Periploca aphylla* Decne.

II. Tropical and North African—Indian Desert Element or The Sudano—Rajasthanian Element—*Acacia senegal* Willd., *Balanites aegyptiaca* Del., *Capparis decidua* (Forsk.) Edgew., *Cleome brachycarpa* Vahl, *Corchorus depressus* Stocks, *Dicoma tomentosa* Cass., *Grewia tenax* Fiori, *Polygala irregularis* Boiss., and *Zygophyllum simplex* L.

III. Mediterranean-Oriental-European Elements—*Anagallis arvensis* L., *Melilotus indica* All., *Vicia hirsuta* Gray, *V. sativa* L., and *Lathyrus aphaca* L.

5. *General Element*

I. Pantropical Element—*Cleome gynandra* L., *Tribulus terrestris* L., *Cardiospermum halicacabum* L., *Tephrosia purpurea* (L.) Pers., *Abrus precatorius* L., *Cassia tora* L., *Vernonia cinerea* (L.) Less., *Ageratum conyzoides* L., *Eclipta prostrata* L., *Celosia argentea* L., *Euphorbia hirta* L., and *Boerhavia diffusa* L.

II. Pantemperate Element—*Ranunculus sceleratus* L., *Veronica anagallis—aquatica* L., and *Fumaria indica* (Haussk.) Pugsl.

III. Cosmopolitan Element—*Oxalis corniculata* L., *Chenopodium album* L., *Solanum nigrum* L., *Cynodon dactylon* Pers., and *Cyperus rotundus* L.

The Indian and Eastern (Indo-Malayan) elements of the flora occur in humid sites and develop mainly during the rainy season. The African element, chiefly xerophytic, is dominant on dry substrata. The presence of this element is considered to be the result of direct land connection between India and Africa. The elements of tropical and warm countries reflect tropical conditions in the region. The temperate and Mediterranean-Oriental elements are dominant during the cold winter period.

IV—THE ALIEN FLORA

The plants that have successfully naturalized in Rajasthan include useful exotics like *Annona squamosa* L., *Prosopis juliflora* DC., *P. glandulosa* Torr., *Parkinsonia aculeata* L., *Pithecellobium dulce* Benth., and noxious or poisonous weeds and pests, e.g. *Acanthospermum hispidum* DC., *Gomphrena celosioides* Mart., *Croton bonplandianum* Baill., *Argemone mexicana* L., etc. Many of them were introduced deliberately for food, fodder,

ornament or afforestation; many came in accidentally and unnoticed. When they arrived at their new home, they were usually further distributed by natural means like wind and water, and aids provided by man and animals, e.g. deforestation, overgrazing, faulty methods of cultivation, nomadism, etc. Some of the plants of alien origin are mentioned below (see also Stockdale, 1940; Purseglove, 1959; Maheshwari, 1961, 1962).

1. Exotics, Escapes and Waifs

Many exotic species have been introduced in the State in connection with the soil conservation and afforestation of dry and desert areas, e.g. *Prosopis juliflora* DC., *P. glandulosa* Torr., *Acacia farnesiana* Willd., *A. tortilis* subsp. *raddiana* Brenan, *Parkinsonia aculeata* L., *Adansonia digitata* L., *Eucalyptus camaldulensis* Dehn., *Ailanthus excelsa* Roxb., *Agave americana* L., and *A. sisalana* Perr. (Badhwar, Dey & Griffith, 1948; Sahni, 1965). Some of them have become naturalized and are a great boon to the dwellers of the region. Besides, a number of plants originally under cultivation in gardens, fields and orchards are found as escapes, e.g. *Ruellia tuberosa* L., *Thunbergia alata* Boj., *Nicotiana plumbaginifolia* Viv., *Corchorus capsularis* L., *Dodonaea viscosa* Jacq., *Clitoria ternatea* L., *Ixora coccinea* L., *Tecoma stans* H.B. & K., *Ipomoea hederifolia* L., and *Jatropha gossypifolia* L. A good number of them are so thoroughly established that they now form a part of the flora, e.g. *Lantana camara* var. *aculeata* Mold. and *Cryptostegia grandiflora* R.Br. In the vicinity of Mount Abu a number of garden plants and cultigens have run wild and occur either as denizens or as waifs, e.g. *Lantana camara* var. *aculeata* Mold., *Solanum seaforthianum* Andr., *Cestrum nocturnum* L., *Tithonia rotundifolia* Blake (syn. *T. tagetiflora* Desf.), *Barleria cristata* L., *Euphorbia geniculata* Orteg., *Ricinus communis* L., *Sesamum indicum* L., *Hibiscus syriacus* L., *Ruta graveolens* L., *Rosa multiflora* Thunb., *Jasminum officinale* L., *Beaumontia grandiflora* Wall., *Vallaris solanacea* Ktze., *Salvia coccinea* Juss., *S. leucantha* Cav., *S. splendens* Ker-Gawl., *Grevillea robusta* A. Cunn., *Thunbergia grandiflora* Roxb., *Asclepias curassavica* L., and *Oenothera rosea* Sol.

The mesquite (*Prosopis juliflora* DC. complex, *P. glandulosa* Torr.) of the arid regions of Mexico and Central America is a notable example among exotic species which have been introduced under the afforestation schemes. The earliest records of its cultivation in India date as far

back as 1877 when the first consignment of seeds was received from Kew, England. The seeds were obtained from the Mohave Desert in Western North America and sown at Saharanpur. It was successfully grown in Jodhpur as early as 1913 and seeds were supplied by the State Forest Department to the adjoining states. The mesquite is found over the greater parts in Rajasthan and adjoining areas. It is a multi-purpose plant, and yields forage leaves and sugary pods for the cattle. In U.S.A. it is considered as the most valuable leguminous tree of the North American forests (Sargent, 1892; McMillan, 1967). The Jerusalem Thorn (*Parkinsonia aculeata* L.), indigenous to Tropical America and S. America has long been used in many tropical countries to form hedges. It was cultivated in the Physic Garden at Chelsea in England by Phillip Miller in 1739 and has since then quickly spread through many warm countries. This tree is naturalized in many parts of the State and is valued for its hardiness, rapid growth and usefulness as a hedge plant (Sargent, 1892). The Manila tamarind (*Pithecellobium dulce* Benth.), indigenous to Mexico, is an early introduction by the Spaniards into the Philippine Islands and then into India. It is cultivated throughout the State near settlements and is often found as an escape from cultivation. The custard apple (*Annona squamosa* L.) is one of the most common American species which is widely naturalized in many parts of India.

2. *Weeds*

The earliest introductions of weeds and weedy plants beginning about 1500 A.D. include species like *Heliotropium indicum* L., and *Malvastrum coromandelianum* (L.) Garcke. In the following years, several exotic weeds became naturalized, e.g. *Lagascea mollis* (Jacq.)Cav. *Xanthium strumarium* L., *Synedrella nodiflora* Gaertn., *Galinsoga parviflora* Cav., *Tridax procumbens* L., *Erigeron canadensis* L., *Datura metel* L., *Martynia annua* L., and *Euphorbia prostrata* Ait. (Brühl, 1908; Merrill, 1954). Many of the weeds mentioned below come from Tropical America and are now naturalized in several parts of the State.

The Tropical American Lantana (*Lantana camara* var. *aculeata* Mold.), which has conquered the countryside so swiftly, was at first cultivated as an ornamental and hedge plant. It achieved its epidemic conquest mainly by birds eating its dark, sweetish fruits and voiding the

seeds to far distant places. It is often found in garden hedges, forest clearings, along roadsides and on neglected slopes in the State changing tracts of bare land into scrub jungles (Santapau, 1964). The prickly pears (*Opuntia* spp.), a native of Mexico, were introduced into India well before 1800 A.D. from Europe with the object of establishing the cochineal industry. Since then it had become widespread in certain parts of India (Burkill, 1911). In 1829 Col. James Tod mentioned in one of his works : "The Castle of Bunai is covered with the cactus or prickly pear so abundant on the east side of Aravalli" (Mehra, 1966). The practice of making fences out of prickly pears and the natural dispersal of their seeds by birds after they had eaten the fruits, greatly contributed to the spread of plants. A long fence of this kind called the "Salt Wall" was made over miles of the Rajasthan border to prevent smuggling. Among the various species of *Opuntia* found in India, the following have been recorded in the State : *O. elatior* Mill. (Mount Abu), *O. dillenii* Haw. (common), and *O. monacantha* Haw. (Sanganer near Jaipur; Alwar). In recent years, this pest had been controlled by the introduction of the moth *Cactoblastis cactorum*. The Mexican poppy (*Argemone mexicana* L.), indigenous to Mexico and other parts of Central America, is widespread in the State, chiefly on recently disturbed soilsand waste lands. The water hyacinth (*Eichhornia crassipes* (Mart.) Solms), a native of Brazil, was introduced into the Old World about 1829 for its decorative flowers. It has been carried all over India and is to be seen in the pools and lakes of Bharatpur and Alwar (Sarup, 1961; Vyas, 1967). *Heliotropium curassavicum* L., a plant of sandy shores and salt marshes has been reported inland from Kuchaman (Rajasthan) and Peshawar (N.W. Pakistan). The weed is believed to be a native of the Atlantic coast of Tropical America and the Caribbean region. It is a fairly recent immigration in the State (Burtt, 1965). In August 1964, I collected an alien species of *Desmodium*, *D. neo-maxicanum* A. Gray growing at Ambaji near Abu Road Station in the undergrowth of the forest. This is the first record of the species from Rajasthan. Among other examples of recently introduced weeds and weedy plants may be mentioned *Alternanthera pungens* H.B. & K., *Gomphrena celosioides* Mart., *Chenopodium ambrosioides* L., *Emex spinosa* Campd., *Evolvulus nummularius* L., *Flaveria trinervia* C. Mohr, *Acanthospermum hispidum* DC., *Carthamus oxyacantha* Bieb., *Ximenesia encelioides* Cav. (syn. *Verbesina encelioides* B. & H.f.), *Ageratum houstonianum* Mill., *Erigeron bonariensis* L., *Ruellia tuberosa* L.,

Oxalis latifolia H. B. & K., and *Croton bonplandianum* Baill. (Nair & Deshpande, 1960; Nair, 1961; Sharma, 1961; Raizada & Sharma, 1962; Puri *et al.*, 1964; Vyas, 1967).

V—CONCLUSIONS

The present state of the flora as it emerges from the above study is characterized by a secondary growth of indigenous and adventive plant species. Man and his associated agents, i.e. cultivation, grazing animals, nomadic food-gathering have played an active role as intentional or accidental carrier of diaspores. Besides, the diaspores of a number of alien and indigenous species (e.g. weeds) are carried into the State by the natural processes of plant distribution, especially dust-storms, squalls, whirlwinds, birds, modern agencies of transport and as seed impurities. An intensified botanical exploration of the State is likely to add more genera and species representing the various elements in the flora, as is demonstrated by recent reports of *Dipterygium glaucum* Decne. (Jain, 1960), *Dactyliandra welwitschii* H.f. (Bhandari & Singh, 1964), *Heliotropium curassavicum* L. (Hingorani & Gaur, 1965), and *Desmodium neo-mexicanum* A. Gray (author's work).

The following means (some of which are already in progress) should be adopted to preserve and utilize the plant wealth of the State: (1) An intensified botanical survey to prepare at least an inventory of the flora. (2) To lay out a living collection of endangered, economic and unique plants in one or more botanic gardens and distribution of living material to other botanical gardens in India and abroad. (3) To watch the introduction, behaviour and ill-effects of exotic species. (4) To make a search for quick-growing exotic and indigenous species to meet specific needs in soil conservation, desert immobilization and afforestation schemes. (5) To direct some research towards biochemical engineering, i.e. to find out what an area will produce most abundantly and then to study the possibilities of its utilization (Pirie, 1960). (6) To lay out properly controlled nature reserves in which the biocoenoses (biotic communities), phytocoenoses (plant communities), gene reservoirs and aliens found in the State may be preserved and studied.

VI—SUMMARY

The flora of Rajasthan comprises several phytogeographical

elements which are common to the adjoining areas of Punjab, Delhi, Gujarat, Uttar Pradesh, Kutch, Saurashtra and Sind. These are grouped into five main classes : (1) endemic element, (2) Indian element, (3) eastern element (Indo-Malayan), (4) western element (Saharo-Sindhian, Sudano - Rajasthanian, Mediterranean - Oriental-European elements), and (5) general element (pantropical, pantemperate, cosmopolitan elements). In contrast to the large number of endemics inhabiting the Himalayas and South India, the State is rather poor in this element. Man and his associated agents, i.e. cultivation, grazing animals and nomadic food-gathering have played an active role as intentional or accidental carrier of diaspores. The present study covers such exotic species which following their immigration or introduction during the historic and modern times have become naturalized and may now be considered as the denizens of the State,

The alien plants that have successfully naturalized in the State include useful exotics like *Prosopis juliflora* DC., *P. glandulosa* Torr., *Parkinsonia aculeata* L., *Pithecellobium dulce* Benth., *Annona squamosa* L., *Nicandra physaloides* Gaertn., *Ipomoea fistulosa* Mart. ex Choisy, and noxious weeds, pests and neophytes, e.g. *Alternanthera pungens* H.B. & K., *Gomphrena celosioides* Mart., *Croton bonplandianum* Baill., *Argemone mexicana* L., *Martynia annua* L., *Acanthospermum hispidum* DC., *Carthamus oxyacantha* Bieb., *Opuntia dillenii* Haw., and *Eichhornia crassipes* (Mart.) Solms. The mesquite (*Prosopis juliflora* DC. complex) of the arid regions of Mexico and Central America has quickly spread on arid barren grounds changing the landscape. It is also threatening to exterminate an indigenous species *P. cineraria* (L.) Macbr. (syn. *P. spicigera* L.) on account of its quick-growing habit, hardiness and survival under vicious grazing by goats. A number of exotic weeds hailing from Tropical America have become an integral part of the flora, e.g. *Lantana camara* var. *aculeata* Mold. *Desmodium neo-mexicanum* A. Gray, a native of Tropical America, is reported for the first time from Rajasthan. The most important factor helping such adventive plants, besides soil and climate, is that they arrived in this country leaving behind all the parasites and natural enemies that had kept them under control in original homes. In conclusion, adequate means should be adopted to save the flora from further devastation. An intensified botanical exploration of the State is likely to add more genera and species representing the various elements in the flora, as is demonstrated by recent reports of *Dipterygium*

glaucum Decne., *Dactyliandra welwitschii* H.f., *Heliotropium curassavicum* L., and author's record of *Desmodium neo-mexicanum* A. Gray. Nature reserves, safe from cattle, nomads and depredators, should be established to preserve and study the biocoenoses, phytocoenoses, gene reservoirs and aliens found in the State.

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Discussion

S.C. Pandeya: You have shown only one species of *Argemone*, viz. *maxicana*. Dr. Mallick of Udaipur reports 2 or 3 species. Could you give some information ?

J.K. Maheshwari : Lately, a second species of *Argemone*, viz. *A. ochroleuca*, indigenous to Tropical America, has been reported from India. This species is spreading on recently disturbed soils and waste lands, particularly in the neighbourhood of Lucknow, Delhi, Ranchi and some parts of Punjab plains.

S C. Pandeya : Is *Annona squamosa* exotic to this State ?

J K. Maheshwari : Yes, *A. squamosa* is a native of South America and the West Indies. It is now widely naturalised in many parts of India. The species is common in the State, especially in the neighbourhood of old forts and on hill slopes and appears to be somewhat indigenous.

S.K. Jain : The chance of *Annona squamosa* being exotic is remote. Its abundance, local names, engraving, etc, on old archaeological objects support its very old occurrence in India.

J.K. Maheshwari : The genus *Annona* consists of more than 50 species, of which many are indigenous to America. A few species are believed to be native of Africa. The paintings and carving referring to this plant are not properly identified and may prove to represent the jack fruit tree or the sacred Kadamba. Further there are authentic records which show that it was introduced.

P.C. Nanda : Ecological amplitude of *Prosopis cineraria* in Indian arid zone is much wider than *P juliflora*. It is not understood how *P. juliflora* is competing with *P. cineraria* particularly when it is not frost hardy.

J.K. Maheshwari : *P. juliflora* on account of its fast growth and survival under vicious grazing is able to compete on arid barren grounds which, otherwise it could have been inhibited by various indigenous species including *P. cineraria*.

A.N. Lahiri : Do you have any data to support your statement that *Prosopis cineraria* is being exterminated by *P. juliflora ?*

J K. Maheshwari : I have often noted in the field that *P. juliflora* as compared to *P. cineraria* is faster in growth, especially in the semi-arid tracts and is also able to survive under heavy grazing and lopping. Further, it often grows to the exclusion of other species, as if it is inhibiting plant growth.

M.N. Tiwari : I think *Acacia tortilis*, *Eucalyptus camaldulensis* could also be included in other flora of Rajasthan.

J.K. Maheshwari : Yes, these species have been successfully introduced in the State under the afforestation schemes. I have included them amongst the list of successful exotic species.

P.C. Nanda : *Prosopis juliflora* is an important firewood plant in the semi-arid region How is it you feel that it needs exterminating particularly when we have an acute fuelwood problem

J K Maheshwari : Our past experience has shown that in many cases indiscriminate introduction of exotic species has caused natural imbalance. The introduction of *P. juliflora* has, however, proved a boon to the dwellers of the region as can be seen from the various uses of the plant.

R K. Gupta : Rajasthan is a very big State with diverse topography and ecological features The author may indicate the area in Rajasthan where the species has naturalised.

J.K. Maheshwari : The areas of naturalisation of alien species are indicated in the paper. However, it is interesting to note that a good number of alien species is found throughout the State under diverse climatic and ecological conditions, e g *Prosopis juliflora*, *Argemone mexicana*, *Acanthospermum hispidum*, *Ipomoea fistulosa*, etc.

Addendum

The number of alien species has increased markedly during the last few decades and demands adequate research on their systematics, identity, nomenclature and growth habits. There are recent reports of misidentifications, misnomers and misapplied names of alien species that have been often confused in the herbaria and in the field with other related taxa, e.g. *Gomphrena celosioides* Mart. (syn. *G. decumbens* auct., non Jacq.; *G. dispersa* auct., non Standl.), *Alternanthera pungens* H. B. & K. (syn. *A. repens* Link, non Gmel.), *Ipomoea fistulosa* Mart. ex Choisy (syn. *I. carnea* auct., non Jacq.), *I. hederifolia* L. (syn. *I. coccinea* Cl., non L.), and *Gnaphalium pensylvanicum* Willd. (syn. *G. purpureum* auct., non L.). The species *Xanthium pungens* Wallr. emend. Widder (Asteraceae), a native of Atlantic North America, has been recently recorded from the region. This taxon is often confused in the herbaria and in the field with the European species, *X. strumarium* L., especially when ripe fruiting heads are lacking in the specimens. Of late years, the South American species *Soliva anthemifolia* R. Br. ex Less. (Asteraceae) has become naturalized in some parts of South-East Rajasthan, namely Atru Village, Kota district, etc. and is gradually spreading to adjoining regions.

FLORAL COMPOSITION OF RAJASTHAN : A REVIEW*

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I—INTRODUCTION

Rajasthan has attracted the attention of our whole nation, and also of the UNESCO, because some parts of the state are arid, and desertic conditions there have caused some alarm. The aridity and other factors influencing the vegetation of the region were discussed in the symposium organised by National Institute of Sciences at Delhi in 1952. The problem of aridity was again discussed in a symposium at Jodhpur in 1964. Some of the important papers presented in these symposia have been included in the bibliography appended with this review. The climates and soils of dry zones, and their influence on the vegetation have been dealt by Waheedkhan (1959), Raheja (1965), Bharucha (1960), Yadav (1960) and Mondol (1967). The works of White (1960) and Christian (1959) review the prospects of fighting aridity and emphasise that with increasing knowledge of science, we can hope to see the deserts blooming.

History of Botanical Exploration

It is a happy coincidence that 1968 is the centennary year of the first recorded plant collections in Rajasthan, which were done by no less a botanical 'giant' than Sir George King. King's collections were made under curious circumstances (Burkill, 1965). About 1866, King was posted as a medical doctor at Calcutta, but he did not keep good health. It was felt that the humid climate of Calcutta did not suit him, and he was posted at drier places such as Agra, Mathura,

and fresh materials are becoming available, some of these have been resolved. The nomenclature adopted in this flora was then fairly uptodate, as compared with earlier works on the region. Plant names, however, keep changing, and some names employed in that work which was prepared about 10 years ago, have changed. Bhandari (1964, 1967) is doing a good job in notifying such name changes as pertain to the plants of Rajasthan.

As regards Mt. Abu, after Macadam's work nothing was written till 1940, when Sutaria (1941) and McCann (1942, 1943) wrote short accounts of vegetation. From 1954 to-date several papers have been published on floristics of this hill by Raizada (1954), Chavan & Sabnis (1960), Kanodia & Deshpande (1961), Jain (1962), Ahluwalia (1965), Kanodia & Rolla (1965), Jain (1967), and Gupta & Saxena (1968).

As regards floristics of eastern parts of Rajasthan, one serious bibliographic anamoly has caught my attention. Most of the workers do not mention Duthie's Flora of Upper Gangetic Plains (1903-22) in their bibliographies. Duthie's work covered major part of southeast and east Rajasthan; none of the workers seem to have kept this jurisdiction of Duthie's work in mind while reporting new records from Udaipur, Kota, etc. Many of these so-called new reports are mentioned by Duthie as common or very common 'in the region of the Flora'. I have dealt with this point only to emphasise that workers on the flora of eastern Rajasthan should consider Duthie's work as a flora already existing for the region. The same applies to the work on grasses by Raizada, Bharadwaja & Jain (1957, 1964, 1966); this also covers eastern Rajasthan.

After Duthie's Flora nothing was written for eastern Rajasthan for about 30 years. Since 1950, a large number of papers has been written on this region and on Aravallis. The full list of these papers will be found in the bibliography. I can refer here only to the work of Mulay & Ratnam (1950), Bakshi (1954), Nair & Nathawat (1956), Joshi (1957, 1958), Sharma (1958), Nair (1961), Nair *et al.* (1959, 1961), Jain & Kotwal (1960), Vyas (1962, 1964, 1965), Raizada & Sharma (1962), Gupta (1965), and Vyas & Ramdeo (1965).

II—FLORAL COMPOSITION

For assessing the present floral composition of Rajasthan, I have tried to bring together all the available information, taking the State

of Rajasthan as a whole. The total Angiosperm flora of Rajasthan comprises about 1280 species, belonging to about 600 genera and 110 families. For various reasons, these figures can not be made absolutely correct. Some names published in lists may be based on wrong identifications; also opinions differ on some names and status of taxa. It has been mentioned elsewhere that some authors do not clearly indicate whether the plants included by them are found wild, or in cultivation or as escapes. Later authors are obliged to use their own judgement or discretion, which may not always be correct. Also, I do not rule out the possibility of some publication having escaped my notice, but I have tried my best to make the figures reasonably correct and uptodate.

I have given below some further analysis of these taxa, namely the largest 10 families, largest genera, etc. I have kept Papilionaceae, Caesalpiniaceae and Mimosaceae as separate families; the limits of other families are almost same as adopted by Bentham and Hooker in Genera Plantarum.

Table 1—The number of families, genera and species in Dicotyledons and Monocotyledons.

	DICOTS		MONOCOTS		TOTAL
	No.	%	No.	%	
Families	92	83.7	18	16.3	110
Genera	465	78.4	123	21.6	593
Species	970	75.8	310	24.2	1280

The largest 10 families in the flora, according to the number of species, are :

1. Poaceae 180 spp. (74 gen.)
2. Papilionaceae 136 spp. (42 gen.)
3. Compositae 86 spp. (51 gen.)
4. Cyperaceae 63 spp. (11 gen.)
5. Acanthaceae 46 spp. (22 gen.)
6. Euphorbiaceae 44 spp. (14 gen.)
7. Malvaceae 40 spp. (11 gen.)
8. Labiatae 35 spp. (13 gen.)
9. Convolvulaceae 35 spp. (11 gen.)
10. Scrophulariaceae 33 spp. (19 gen.)

The following 10 families have the largest number of genera :

1. Poaceae 74 gen. (180 spp.)
2. Compositae 51 gen. (86 spp.)
3. Papilionaceae 42 gen. (136 spp.)
4. Acanthaceae 22 gen. (46 spp.)
5. Scrophulariaceae 19 gen. (33 spp.)
6. Asclepiadaceae 16 gen. (20 spp.)

7. Euphorbiaceae 14 gen. (44 spp.)
8. Cucurbitaceae 14 gen. (24 spp.)
9. Labiatae 13 gen. (35 spp.)
10. Rubiaceae 13 gen. (19 spp.)

If the Leguminosae is taken as one family, it comprises 51 genera and 177 species. Even then Poaceae remains at top in both the lists; and the Ist and 2nd places are retained by Leguminosae and Compositae. Cyperaceae has a high (4th) place in the first list, but none in the second, because the genus *Cyperus* alone contributes about half the number of species of the family; the family has 11 genera.

The following are some of the large genera in the flora : *Cyperus* (30 spp.), *Indigofera* (20 spp.), *Euphorbia* (18 spp.), *Eragrostis* (15 spp.), *Crotalaria* (15 spp.), *Grewia* (14 spp.), *Ipomoea* (14 spp.), *Cassia* (13 spp.), *Tephrosia* (12 spp.), *Alysicarpus*, *Heliotropium*, *Acacia* (all 11 species).

Poaceae, which is the largest family of the region, has only one large genus; large number of smaller genera is responsible for giving it a high place in the list. Four out of the above genera belong to Papilionaceae.

III—GENERAL VEGETATION AND ECOLOGY

We can not visualise the flora of a region by merely knowing what families, genera and species occur there; it is necessary to know what plants form the dominant vegetation cover, in trees, shrubs and ground flora. Also, the dominant species in different habitat conditions must be known. This brings us to the study of phytosociology or synecology or, in a broad sense, the vegetation types. Vegetation types of Rajasthan have been described by Champion (1936), Mathur (1960), Puri and Jain (1961), Jain (1963), Champion and Seth (1964), and Mathur and Verma (1964). Ecological accounts of Rajasthan as a whole or smaller regions have been published by Bharucha (1951), Sarup (1952), Agharkar (1952), Biswas (1952), Puri (1952), Joshi (1956, 1958), Satyanarayan (1963), Vyas and Ramdeo (1964), Sharma (1962, 1965), Sen (1966), and Verma (1967).

I would have liked to make a special mention of the history and progress of work on grasses and grasslands (a subject of my particular interest), as also of certain other special groups like aquatic vegetation, sand-dune vegetation, etc. Limitation of space forbids me from doing it. I have, however, included all such references in the bibliography. Also, evidently, I have covered only the higher plants. Not that the study of

other groups of plants is less important; my personal limitations alone are responsible for this partiality. The work of Gupta (1962) on the genus *Marsilea* is known far outside the boundaries of our country. The ferns of Mt. Abu have been studied by Bir (1961) and the Hepatic flora by Bapna (1958).

IV—PHYTOGEOGRAPHIC CONSIDERATIONS

Phytogeographically, the western and northwestern Rajasthan has always been regarded as almost a distinct unit in Indian vegetation. Clarke (1898) called this region as 'Indian Deserta'. Hooker (1907) and Chatterji (1935) called it as the 'Indus Plain'. The flora has resemblance with arid regions of Pakistan and even of Arabia and Africa.

The flora of Aravallis and eastern Rajasthan is dissimilar from western Rajasthan. This point was brought out as early as 1878 by King. The flora of Mt Abu is of particular phytogeographic significance. Jain (1967) has shown that this hill has served as a meeting ground for the north Indian and peninsular elements of flora in India. Mt. Abu is the northernmost limit for certain plants of peninsular region, and the southernmost limit for certain Himalayan or north Indian plants.

V—ENDEMISM

The only notable work on endemism was by Chatterji (1939) 30 years ago. Rajasthan lies in the zone of poor endemism, and, as far as we know even today, the flora does not show high endemism. I think, there are two main reasons for this. Firstly, the area is not 'isolated', i.e. the conditions of environment and soil are such as occur widely in the neighbouring regions; they are not exclusive to the region. Mt. Abu, isolated to some extent from the surrounding territory, due to its altitued, does have some endemic taxa. Secondly, the flora is still incompletely known. Endemism in Rajasthan could, in fact, be studied at two levels : plants endemic to Rajasthan State alone, and plants occurring in Rajasthan endemic to the country. No work has been published on endemism in Rajasthan alone. Some taxa described by Blatter and Hallberg (1918-21) and by Blatter and McCann (1926-35) have not still been reported from elsewhere, and

can be considered to be endemic. The same applies to the various taxa described recently from Rajasthan. As regards the second aspect, out of 134 dicot genera listed by Chatterji (1939) as endemic to India, only six, namely *Ougeinia*, *Butea*, *Caesulia*, *Glossocardia*, *Petalidium*, and *Haplanthus* are reported to occur in Rajasthan.

VI—ECONOMIC ASPECTS

It is often impossible to draw a line between floral composition, forest wealth or medicinal resources; I have, therefore, included some more important papers on these subjects in the bibliography. I would recall here that it was in 1869 and 1870 that King wrote two papers on famine foods of Rajasthan. I have come across in literature one still earlier reference 'Some account of the general medical topography of Ajmer' published in 1843 by Irvine but I have not been able to have a look at this work.

VII—PROSPECTS OF FUTURE FLORISTIC STUDIES

There is practically no region in Rajasthan which we could call 'virgin' in true sense, yet some publications are very sketchy and such areas could be called as unexplored. Although certain places like Jodhpur, Pilani, Abu and Alwar, have been fairly well explored, we can not label them as fully explored, until detailed floras for these are published. The three categories on the basis of explorations and publications are as follows :

(i) *Fairly explored* : Sirohi (including Mt. Abu), Jodhpur, Jhunjhunu, (Pilani) and Alwar.

(ii) *Under-explored* : Udaipur, Sikar, Churu, Ajmer, Jaipur, Barmer, Jaisalmer.

(iii) *Unexplored* : The remaining areas.

A stage has certainly been reached now, when, firstly, a check-list for Rajasthan should be published; and secondly, monographic work should be taken up on genera and smaller families. The *Check-list*, which should include important synonymy and cross references, will help in two ways. It shall enable workers to filter their suspected new records from Rajasthan, and it will bring about consistency in nomenclature in future publications. Monographic studies will enable intensive work on fewer taxa, and will result in resolving many

misidentifications, nomenclatural riddles and in discovery of new taxa. Authors of floristic accounts deal with hundreds of taxa, and they can not always be very critical. Small problems of this nature could be worked out for M.Sc. or Ph.D. theses.

I would like to mention here something about publication of research findings. It is understandable if copies of Macadam's work or King's work may not be available to many people; but how to reconcile with non-availability, or poor circulation of publications of late 20th century. Authors publishing papers in University journals (or even College magazines) and other less known periodicals should take special care that their papers are notified in some abstracting journals. It is gratifying to note that during last 10 years or so the quality of floristic papers has greatly improved. Authors would do well by always including some important or prevalent synonyms in their lists, and by clearly indicating if a plant is truely wild, an escape, or under cultivation. With the concerted efforts of all interested in flora of Rajasthan, we can hope that Rajasthan will be the first State in India to say '*We know our flora.*'

VIII—SUMMARY

The desertic conditions in certain parts of Rajasthan have become a matter of concern to the country and it is only very proper that a stock is periodically taken of the natural resources of the region. Since 1960 there has been a regular flow of publications on botany of Rajasthan. The progress of this exploration has been reviewed.

The flora of Rajasthan, as now known, comprises about 1280 species belonging to 600 genera and 110 families. The ten largest families are *Poaceae*, *Papilionaceae*, *Compositae*, *Cyperaceae*, *Acanthaceae*, *Euphorbiaceae*, *Malvaceae*, *Labiatae*, *Convolvulaceae* and *Scrophulariaceae*. The ten largest genera are : *Cyperus*, *Indigofera*, *Euphorbia*, *Eragrostis*, *Crotalaria*, *Grewia*, *Ipomoea*, *Cassia*, *Tephrosia* and *Alysicarpus*. The ratio of Dicots to Monocots is : families 5 : 1; genera 4 : 1, and species 3 : 1.

Reference has been made to phytogeography, endemism, ecology, vegetation types and economic aspects of the flora.

Prospects of future floristic studies in Rajasthan are discussed. Jodhpur, Sirohi (Mt. Abu), Jhunjhunu and Alwar are considered to be fairly well explored districts. A stage is now reached that a check-list of the flora of Rajasthan should be prepared. Also, monographic

work on some genera and small families should be undertaken. It is hoped that in about 10 years time, Rajasthan can become floristically the best studied State in India.

A bibliography of about 275 references, with full titles of papers and books, is appended. Certain important bibliographic and review works on taxonomy and nomenclature have been suggested as valuable aids in the study of flora.

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STUDIES ON THE ALGAE OF CERTAIN HABITATS ENDEMIC TO RAJASTHAN

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(With 4 Text-figures)

I—Introduction

Rajasthan, with an area of 34,2272 sq. km., is situated in the northwestern part of India between 23°3'N and 30°12'N latitude and 69°30'E and 78°170'E longitude, and has a topography dominated by the Aravalli mountain system which runs across the State from northeast to southwest for nearly 692 km. The 50 cm rainfall line divides the State into two distinct climatic regions, the dry and the humid. The dry area, northwest of the Aravallis, includes both arid and semiarid conditions and is characterized by vast stretches of desert with long periods of severe drought accompanied by low night- and high daytemperature, low relative humidity, low annual rainfall (well below 50 cm), high wind velocity and sparse xeric vegetations, and the area southeast of Aravallis remains humid with 50 cm or more annual rainfall and has in general more fertile soil and consequently a better developed vegetation.

Virtually no work has been done on the ecology of algae of Rajasthan and on the role these algae play in the economy of natural ecosystems. Singh (1955) described the plankton of Sambhar salt lake and of Nakki lake at Mt. Abu with no mention of the chemical nature of these aquatic habitats and their limnology. Vyas and Kumar (1968), after making intensive study of the succession of the phytoplankton of Indrasagar tank situated near Eklingji, observed excellent correlation between algal population pulse and fluctuation in physicochemical character of the tank. This paper describes the work done on the algal ecology of certain habitats endemic to Rajasthan, i.e. desert, mine wastes, salt lakes, fresh-water lakes, and sewage, and

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Discussion

R. K. Gupta : (1) Sermolli's classification for vegetation type may be substituted by International System of Classification, (2) *Lagerstroemia* and other plants are cultivated in Badabag and do not give an idea of the natural dry deciduous forest in the area.

S K. Jain : (1) Champion and Seth's classification is yet to be seen. Few years ago when this work was not available Sermolli's work seemed to fit our types best. There is still much difference of opinion about a uniform terminology and classification types. (2) Yes, I said they are gardens of maharajas and are not natural vegetation types of Rajasthan.

belonging almost exclusively to the Cyanophyta, have been collected from these areas though the endolithic algae have not been studied.

The micaceous rocks found in different areas in Rajasthan support good growths of *Scytonema, ocellatum, Stigonema* spp., *Fischerella moniliformis, Hepalosiphon confervaceous, H. intricatus, Schizothrix mascarenica, Porphyrosiphon notarisii, Aphanotheca pallida, Nostoc commune*, and species of *Chroococcus* and *Gloeothece*. Such algae are at their best during the months of July, August and September immediately after the rains. According to Singh (1961) the rocks of Mt. Abu, which consist of granite, quartz, biotite and felspar with hornblende, support a distinctive flora of blue-green algae including such species as *Tolypothrix byssoidea, T. saxicola, Scytonema julianum* and *Calothrix parietina.*

Biological and cultural studies on the algae of Rajasthan rocks have not yet been carried out. Nevertheless it would not be illogical to suppose that at least some of them, e.g., species of *Tolypothrix, Scytonema, Calothrix, Nostoc, Fischerella* and *Hapalosiphon*, may contribute significantly to the nitrogen status of their respective habitats by fixing atmospheric nitrogen. Furthermore, such algae not only enrich the organic content of the rock making it suitable for subsequent colonization by higher plants, but also exert a corrosive action that is responsible for the weathering of the rock; the weathered material is then deposited in the surrounding localities and contributes to their fertility.

The second important type of algal habitat is afforded by certain diaphanous substrata, such as quartz or other minerals, which are partially embedded in the surface of desert soil. The chief characteristic of diaphanous substrata is their translucency and this permits the existence on their lower side of relatively mesophilic algal species that do not normally occur as components of xeric soil populations. In the Rajasthan desert some commonly occurring translucent materials in association with algae are gypsum, quartz, bones and teeth of dead cattle, and shells of various molluscs. The Central Aravalli area of Rajasthan is an important producer of mica, felspar, quartz, beryllium and other ores, and it has been observed that algae can be found under the layers of mica or felspar. The diaphanous minerals tend to create a miniature green-house environment below their embedded surface and ecological factors such as light intensity and quality, organic matter-biotic relationships and associations, temperature, and moisture content are altered in such a way as to enable the existence of various soil algae

attempts to assess the importance of algae in natural resources of Rajasthan.

II—ALGAE OF THE RAJASTHAN DESERT

The desert areas of Rajasthan constitute an environment that is too harsh to permit growth of any macrovegetation. But at isolated spots within the desert certain favourable ecological niches or micro-environments are found that support meagre growths of terrestrial microalgae, bacteria and lichens. Such plant communities as exist in the prevailing desert environment usually include xeric ecotypes that have become adapted to survive in rigorous arid environments.

The salient features of the arid environment include a deficiency or lack of moisture, intense sunlight that is relatively richer in infra-red and ultraviolet rays, too high or too low temperatures, and a general paucity of food supply, soil nutrients and organic matter. Of all these factors, water is perhaps the most critical and other harsh factors such as intense sunlight, high winds, high day-time temperatures and the presence of salts in the soil mostly exert their effects by further accentuating the already unfavourable moisture conditions.

Algal habitats in the Rajasthan desert are of two main types; Type 1 includes arid and semiarid soils, sandy soils, bare rocks and rock fissures, and Type 2 includes various kinds of diaphanous or translucent substrata that are partially embedded in desert soils and provide favourable microenvironments on their under side for algal growth.

III—SOIL ALGAE AND ROCK ALGAE

Certain species of blue-green algae and green algae are known to occur both on the surface of and within the soil in many desert regions of the world (Cameron and Blank, 1966; Friedmnan *et al.*, 1967). Although no studies on such epedaphic or endedaphic algae from the Rajasthan desert seem to have been carried out, their occurrence in such endemic habitats, especially during the rainy season, may safely be assumed.

Singh (1961) and Kumar (unpublished) have carried out preliminary and exploratory studies on the algal flora of Rajasthan rocks. The main places studied so far are Jaipur, Ajmer, Jodhpur, Mt. Abu, and Udaipur and its environs. Both lithophytic and chasmolithic algae,

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2-3 cm thickness. The lake is very rich in sodium chloride and sodium sulphate with the year-round percentage variation of 60-96%. This variation results mainly from lowering down of water level in the lake due to solar evaporation.

The chemical analysis of the lake mud and brine water for quantitative estimation of nitrogen, sulphur and phosphorus revealed that the black mud contains 0.792 per cent nitrogen, 0.32 per cent sulphur and 0.15 per cent phosphorus and the brine water shows nitrogen 28 mg/l, sulphur 12 mg/l and phosphorus 4 mg/l. The pH of the black mud was 8.5 and that of brine water 9.0. Similarly alkalinity determination gave a result of 210 mg/l for black mud and of 415 mg/l for brine water. These data indicate the nutritionally-rich nature of the lake but its unusually high concentration of brine makes the lake a very specialized habitat unsuitable for algal species growing in normal habitats. The constant failure of our repeated attempts at growing any of the Sambhar salt lake algae in all the conventional culture media tried indicates some unique physiological characteristics which make these algae thrive and multiply in unusually high concentrations of brine.

The period September to December is very suitable for the growth of Sambhar lake algae and during this period cartloads of dark blue-green algal mats, locally known as "neel" and consisting of *A. circularis* and *S. plantensis*, are produced on the water surface and along the sides of the lake. The algal growth is so profuse and prolific that labourers have to be hired to remove the algal mats from lake since they create great trouble during salt manufacture. The Assistant Chemist of Sambhar Salt Lake Department informed us that the "neel" is employed on a large scale as green manure by local farmers.

The question arises as to what is the source of nitrogen in the lake water or lake black mud. Though *A. circularis* could not be cultured yet, the suggestion (Singh, 1961) that this alga could be a vigorous nitrogen fixer enriching the lake with fixed nitrogen should be considered favourably till some evidence contrary to this suggestion is brought forth. However, the growth in bulk of algae in Sambhar lake creates problems in salt manufacture by imparting colour to brine and this makes it essential to check the algal growth. In this respect it is rather unfortunate not to find any reference to the algal flora of Didwana and Pachpadra salt lakes and if these lakes have not yet been studied, it is high time that their biological productivity was investigated.

on their under-surface. Algae which have been found to be commonly associated with diaphanous substrata include species of Chroococcales (Cyanophyta) and Chlorococcales (Chlorophyta). The main adaptive feature of such coccoid algae appears to be their capacity to perennate as such.

As is well-known, quartz, unlike ordinary glass, can transmit ultraviolet light which is harmful and mutagenic to living organisms including algae. In tropical deserts, exposed to intense sunlight, the radiation that strikes a quartz stone is likely to contain a significant proporation of deleterious ultraviolet rays and these may be expected to produce adverse effects on algae growing on the under-surface of the translucent substratum. However, experiments carried out in the laboratory on a unicellular blue-green alga *Anacystis nidulans* (Kumar, 1963) have demonstrated that these forms can successfully be trained to withstand the deleterious and inhibitory effects of repeated doses of short wave-length ultraviolet radiation. Such studies point to the occurrence of widespread natural adaptation to ultraviolet in algae associated with diaphanous substrata, an adaptation that is of obvious biological advantage.

IV—ALGAE OF THE SALT LAKES

Rajasthan includes three salt lakes, namely Sambhar lake in Jaipur division, and Didwana and Pachpadra lakes in Jodhpur division. Singh (1961), during his preliminary survey of the algal flora of Sambhar lake, reported the occurrence of one species of blue-green-algae, *Anabaenopsis circularis*, and on the basis of fragmentary information supplied by the Sambhar Lake Salt Department suggested the justified use of lake black mud as a good source of fertilizer.

In our investigation of the composition of algal flora of Sambhar lake two collections were made, one in October, 1967 and the other in June, 1968. Both collections revealed the presence of *Chlamydomonas*, *Spirulina platensis* and *Anabaenopsis circularis*. In October while *Chlamydomonas* and *S. plantensis* were found growing in fine suspension, *A. circularis* formed a many layered thick scum on the surface of brine water. Since the lake is very shallow (about 4 feet deep) and becomes easily over-flooded in rainy season it dries up in summer and these algae perennate in lake mud lying just below the salt layers of approximately

2-3 cm thickness. The lake is very rich in sodium chloride and sodium sulphate with the year-round percentage variation of 60-96%. This variation results mainly from lowering down of water level in the lake due to solar evaporation.

The chemical analysis of the lake mud and brine water for quantitative estimation of nitrogen, sulphur and phosphorus revealed that the black mud contains 0.792 per cent nitrogen, 0.32 per cent sulphur and 0.15 per cent phosphorus and the brine water shows nitrogen 28 mg/l, sulphur 12 mg/l and phosphorus 4 mg/l. The pH of the black mud was 8.5 and that of brine water 9.0. Similarly alkalinity determination gave a result of 210 mg/l for black mud and of 415 mg/l for brine water. These data indicate the nutritionally-rich nature of the lake but its unusually high concentration of brine makes the lake a very specialized habitat unsuitable for algal species growing in normal habitats. The constant failure of our repeated attempts at growing any of the Sambhar salt lake algae in all the conventional culture media tried indicates some unique physiological characteristics which make these algae thrive and multiply in unusually high concentrations of brine.

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The question arises as to what is the source of nitrogen in the lake water or lake black mud. Though *A. circularis* could not be cultured yet, the suggestion (Singh, 1961) that this alga could be a vigorous nitrogen fixer enriching the lake with fixed nitrogen should be considered favourably till some evidence contrary to this suggestion is brought forth. However, the growth in bulk of algae in Sambhar lake creates problems in salt manufacture by imparting colour to brine and this makes it essential to check the algal growth. In this respect it is rather unfortunate not to find any reference to the algal flora of Didwana and Pachpadra salt lakes and if these lakes have not yet been studied, it is high time that their biological productivity was investigated.

V—Algae of Zawar Mines

Zawar Mines, situated in Udaipur division of Rajasthan, are a rich source of zinc ores also containing significant quantities of lead, silver and cadmium. Mine wastes cansisting of highly turbid water solution of suspended rock, soil and ore particles are produced in large quantities during ore extraction. These mine wastes are disposed off through open drains into a big reservoir exclusively meant for this purpose. The semiaquatic and aquatic habitats resulting from disposal of mine wastes are unusual for the growth of plants including algae because of their containing high concentrations of zinc (8 mg/l), lead (5 mg/l), cadmium (1.5 mg/l) and copper (2.5 mg/l). Though zinc and copper are essential microelements for algal growth, both elements become toxic if their concentrations are increased above a certain specific level (Eyster, 1964). To our knowledge, no reports are available regarding the effect of lead, silver and cadmium on the physiology of algae. The present interest in the study of algal flora in relation to some chemical factors stems from the fact that such habitats are bound to provide useful information about the tolerance range and ecology of Rajasthan algae since concentrations of mineral elements in the mine wastes of Zawar Mines are well above the normal tolerance range and requirement of algae.

The algal flora shows a preponderance of diatoms, i.e. *Cymbella*, *Navicula*, *Synedra*, *Nitzschia*, *Amphora*, *Mastogloia* and *Melosira* including two species of *Ulothrix*, i.e. *U. zonata* and *U. variabilis*, and one species of *Spirogyra*. These algae are found growing on the sediments of mine wastes and the mine-waste effluent does not support any growth.

VI—Sewage Algae

Safe disposal of sewage is of utmost importance from sanitary point of view and the only cheap and easy way is to dispose it off in large bodies of water, i.e. lakes, rivers and sea, where the sewage gets diluted and mineralized or digested by the joint action of aerobic bacteria and photosynthetic algae.

Sewage microbiology of Rajasthan is completely unexplored. In view of the absence of any perennial rivers in Rajasthan the creation of sewage oxidation ponds should be encouraged. In Udaipur, where the authors are currently interested in assessing the role of algae in sewage oxidation, the city sewage is carried through malodorous open drains.

These drains open into Ayier river which remains almost dry throughout the year except for a period of 2-3 months in rainy season. However, the river basin contains many scattered deep depressions in which sewage gets collected and these depressions serve as sewage ponds of perennial nature. In rainy season the river does not support any planktonic algal growth because its rain water along with sewage water remains flowing. But from October till June the river remains almost dry and the stagnant sewage ponds of river basin favour luxuriant growth of species of *Chlamydomonas*, *Scenedesmus* and *Euglena*. The population size of sewage algae fluctuates considerably with *Scenedesmus* as the dominant alga of winter community with concentrations of $4\text{-}36 \times 10^5$ cells/ml and during this season the concentrations of *Chlamydomonas* and *Euglena* are approximately $2\text{-}8 \times 10^3$ and $5\text{-}16 \times 10^3$ cells/ml respectively. From February onwards, the population of *Scenedesmus* starts declining and that of *Chlamydomonas* and *Euglena* rising and by the end of March the sewage algal flora includes species of only *Chlamydomonas* and *Euglena* with population size of approximately 5×10^4 and 2×10^3 cells/ml respectively. The pH of sewage ponds remains nearly 8.5 throughout the winter and summer season while alkalinity varies between 350 and 410 mg/l with comparatively higher alkalinity in summer.

The role of algae in sewage digestion and disposal has been well documented (Isaac and Lodge, 1958; Singh, 1961). The sewage treatment is essentially a biological process involving aerobic bacteria and photosynthetic algae, the former breaking down the organic wastes of sewage to simple mineral nutrients at the cost of oxygen produced by algae during photosynthesis and the latter growing at the expense of mineral nutrients and carbondioxide resulting from bacterial activity. The microbiological method of sewage treatment should be encouraged mainly due to two economic reasons. Firstly, the potentially noxious and dangerous sewage is made harmless and, secondly, the nurtients tied up in sewage get incorporated into algal cells which along with the effluent of treated sewage can be utilized for fertilizing fish ponds. This line of approach of sewage disposal in Rajasthan seems quite feasible as most of the freshwater lakes of this State, particularly of Udaipur, are employed for fish cultivation on a commercial scale.

VII—ALGAE OF UDAIPUR LAKES

Udaipur has three lakes, i.e. Pichola, Fateh Sagar and Swarup Sagar,

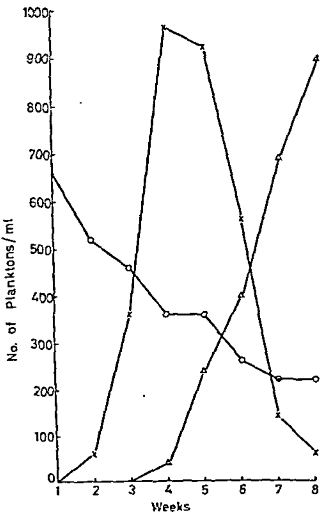
with more or less a common phytoplankton flora consisting of *Pediastrum duplex*, *Selenastrum westii*, *Ankistrodesmus*, *Scenedesmus*, *Coelastrum*, *Cosmarium*, *Closterium* (Chlorophyceae), *Chrysococcus* (Chrysophyceae), *Microcystis aeruginosa Merismopedia punctata*, *Anabaenopsis raciborskii*, *Anabaenopsis arnoldii*, (Cyanophyceae), *Mastogloia* and *Navicula* (Bacillariophyceae). The pH ranges from 8-8.5 and water analysis conducted during the month of April gives values of approximately 30 mg/l of alkalinity. A regular monthly survey of the lakes for nearly two years gave no indication of heavy algal blooms. However, summer rather than rainy or winter season seems to favour better algal growths as evidenced by summer occurrence of more types of algae in relatively much greater numbers.

Pichola lake remains highly polluted due to constant addition of sewage from lake palace and from motor boats and so is the case with Swarup Sagar and Fateh Sagar where washerman make large-scale routine use of lake water for washing clothes of the city population. All the three lakes are used for fish cultivation on an industrial scale, most of the species cultivated being well-known feeders of phytoplanktons as well as of protozoans and crustaceans which in turn feed exclusively on planktonic algae. In view of the known role of algae in sewage digestion and in fish food-chain, the biological productivity of Udaipur lakes is worth investigating.

VIII—ALGAE OF VILLAGE PONDS

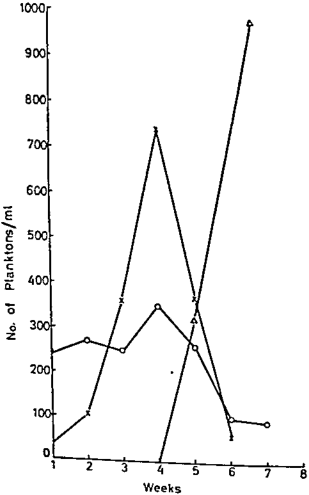
Periodicity of a few selected early summer algae growing during the period from March to April in two representative village ponds of Udaipur was studied in relation to some nutritional and other chemical factors. The two ponds conveniently designated as pond$_1$ and pond$_2$ frequently receive good amount of domestic pollution which makes them organically very rich. Pond$_1$ and pond$_2$ differ in the composition of ephemeral summer phytoplankton and this distinctive feature of the two ponds provided excellent opportunity to investigate the nature of ecological factors involved in the regulation of algal periodicity.

The algae recorded in pond$_1$ are *Chlamydomonas*, *Chlorella* and in pond$_2$ are *Gonium*, *Pandorina* and *Euglena*. The examination of Fig. 1 suggests that *Chlorella* is the initial dominating alga of pond$_1$ and though its number continues falling from the very beginning, its dominance



Text-fig. 1—Weekly variation in population density of *Chlamydomonas* (×—×), *Chlorella* (○—○) and *Euglena* (△—△) in pond$_1$.

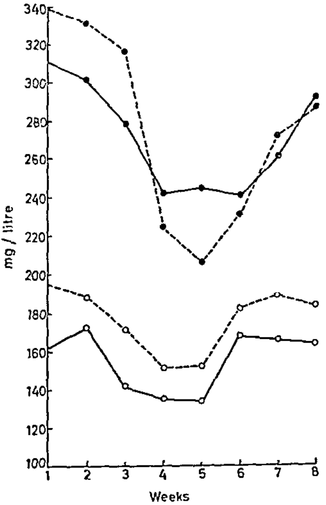
persists till the 3rd week of March. The peak abundance of *Chlamydomonas* lies between 4th and 5th week after which the alga gives way to *Euglena* which dominates till the end of the growing season. The quantitative data of relative abundance given in Fig. 2 indicate both *Gonium* and *Pandorina* attaining peak density in the 4th week, with *Gonium* dominating the algal flora till the 2nd week after which *Pandorina* becomes the dominating partner. In the 5th week there was



Text-fig. 2—Weekly variation in population density of *Pandorina* (X—X), *Gonium* (O—O) and *Euglena* (Δ—Δ) in pond$_1$.

a decline in the *Gonium* and *Pandorina* population followed by sudden appearance and rise in the population density of *Euglena* which attained maximum frequency by the 6th week.

Both the ponds have a similar pattern of alkalinity variation, initially showing gradual fall between the 2nd and 5th week and then slow rise form 5th week onwards (Fig. 3).



Text-fig. 3—Weekly variation in alkalinity (•—•) and phosphate (O—O) content of pond₁ (———) and pond₂ (- - - -).

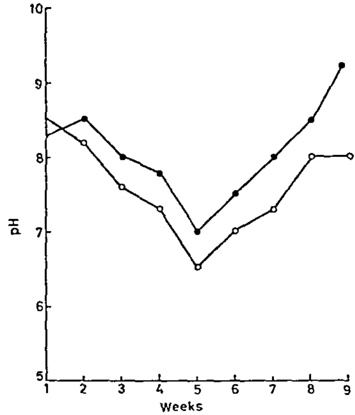
In pond₁ the decrease in alkalinity is accompanied by the decrease in *Chlorella* faequency and increase in *Chlamydomonas* frequency while in pond₂ the density of *Gonium* and *Pandorina* becomes greater with the lowering of alkalinity. But the rise in alkalinity after 5th week brings down considerably the relative abundance of the initial algae and not of *Euglena* which seems to prefer higher alkalinity for good growth. *Similar trend is evident in respect of weekly fluctuations* in phosphate content and algal abundance (Figs. 1, 2 and 3).

Weekly variations in nitrate and ammonium nitrogen of $pond_1$ and $pond_2$ were also studied. Nitrate in $pond_1$ showed a little depression in the 2nd week and thereafter it continued to rise becoming almost constant after 5th week. $Pond_1$ had ammonium nitrogen maximum in the 2nd week, minimum between the 2nd and 4th week and moderate after 4th week. The decrease in the concentration of ammonium nitrogen followed by rise in the population density of *Chlamydomonas* points towards preferential utilization of ammonium nitrogen over that of nitrate nitrogen by the alga.

$Pond_2$ always contained higher amount of ammonium nitrogen than nitrate nitrogen. The difference and fluctuation in the quantity of the two kinds of nitrogen are more likely to result from the microbiological processes operating within the pond. Moreover, *Gonium* and *Padorina* may prefer nitrate rather than ammonium nitrogen and consequently any increase in their population size is bound to result in lowering the nitrate concentration and this is precisely what the nitrogen data of $pond_2$ suggest.

The pH fluctuations are identical in both the ponds with a minimum value in the 5th week, and $pond_1$ remained more alkaline than $pond_2$ throughout the course of the investigation (Fig. 4). The variation in pH seems not to be influenced by any factors other than the variation in alkalinity whose fluctuations, to a large extent, appear to be dependent on the size of algal population. The one obvious inference that can be drawn from the present study is that higher alkaline pH favours the growth of *Chlorella* and *Euglena* and slightly acidic or alkaline conditions promote the growth of *Chlamydomonas*, *Gonium* and *Padorina* (Figs. 1, 2 and 4).

Both $pond_1$ and $pond_2$ are nutritionally sufficient to promote and support static algal growths but the way the composition and the relative abundance of pond algae varies, suggests that nutrition is not a factor controlling algal periodicity in $pond_1$ and $pond_2$. These results indirectly support the involvement of the products of one alga in creating conditions conducive to the growth of some other, and suicidal for itself. In fact, no observations on the production of active metabolites were attempted during the present study and the possibility of their participation in regulating the algal periodicity in the two ponds cannot be ignored.



Text-fig. 4—Weekly variation of pH in pond₁ (•—•) and pond₂ (O—O).

IX—SUMMARY

A general study of the algal flora of certain habitats endemic to Rajasthan has been made in relation to some physicochemical factors with a view to studying the tolerance-range ecology of Rajasthan algae and to assess their role in the biological productivity of their respective habitats.

Desert habitats comprising semiarid and arid soils, bare rocks, *rock fissures and diaphanous substrates and providing very harsh growth* conditions have algal flora consisting predominantly of nitrogen fixing blue-green algae which contribute towards the nitrogen and organic status of such habitats. The mine waste algae of Zawar Mines are mostly diatoms including a few other algae. The mine wastes are

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GRASSLAND IMPROVEMENT IN DRY AND ARID TRACTS OF RAJASTHAN

By

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I—INTRODUCTION

Rangeland husbandry occupies a prime place in the economy of Rajasthan because of unfavourable and trying climatic conditions that exist more especially in the western part of the State; most of the area being climatically classified as arid, semi-arid and dry. Livestock industry also forms the main occupation of the major portion of the population of the State. The problem of animal nutrition is, however, of great magnitude arising out of the very high livestock population of the State (33.5 million in 1961—Whyte, 1964), the prevailing grazing practices and other social and religious customs in the country. The number of cattle units per 100 grazing hectare units has been calculated to be 177 in western Rajasthan (Ganguli, 1964). There is thus heavy incidence of grazing on the available lands resulting in their progressive deterioration to a 'poor' condition and severe soil erosion, to provide only below subsistance feed to livestock which in turn is reflected in their poor yield of milk, wool and meat.

Inspite of the very trying climatic conditions over the greater part of the State, these dry and arid areas are capable of higher production than otherwise conceived. During and after the monsoon period these areas are turned into vast grasslands, which if managed properly could be maintained as excellent pastures. Reconnaissance grassland surveys in Rajasthan, which have classified the grasslands of the dry and arid areas of the State into *Dichanthium-Cenchrus-Elyonurus* grass cover, have revealed a high potential of such nutritious and palatable grasses like *Lasiurus sindicus* (*Elyonurus hirsutus*), *Cenchrus ciliaris*, *C. setigerus*, *Dichanthium annulatum* and *Panicum antidotale* (Dabadghao, 1960, 1960a; Prakash & Ahuja, 1964). The extent of grazing lands varies from 30 to 80 per cent of the land area in different districts of the State (Raheja & Sen, 1964).

nutritionally poor and have concentrations of zinc, copper, lead and cadmium well above the normal tolerance level of algae of normal habitats.

Inspite of the Sambhar salt lake being nutritionally sufficient, only *Chlamydomonas*, *Spirulina platensis* and *Anabaenopsis circularis* grow in this lake. The obvious factor preventing growth of other algae seems to be the high pH since cartloads of blue-green algae are produced and employed by local farmers as green manure. The Udaipur lakes are eutrophic supporting mostly members of Chlorococcales including a few blue-green algae. The lake algae are never observed in blooms perhaps due to their serving as a source of food for the fishes of the lake. The sewage ponds supporting the growths of *Chlamydomonas*, *Scenedesmus* and *Euglena* are alkaline, being very rich in nitrate, ammonium and phosphate. The periodical changes in the relative abundance of the village pond algae are accompanied by variations in chemical characters of the pond water and an apparent correlation seems to exist between them. The pH study suggests that higher alkaline pH favours the growth of *Chlorella* and *Euglena* and slightly alkaline or acidic conditions promote the growth of *Chlamydomonas*, *Gonium* and *Pandorina*.

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condition grasslands in kg/ha respectively was: 337 to 688, 552 to 869, 703 to 1523, 1165 to 1748, the increase being largely due to the improvement in grass cover and steady increase in perennial grass species. In the grasslands on heavy soils with higher rainfall the yield of forage increased by over 100 per cent while the increase in yield in low rainfall tracts was about 50 per cent (Anonymous, 1964).

Preliminary studies on improvement of grassland in Chambal ravines at Kota have indicated that these degraded ravine lands would yield over 5,700 kg/ha (green weight) of grass annually after 3 to 4 years of simple closure, if the grasses are cut twice in the season (Kaul, 1962b). The average yield of grasses increased from 3464 kh/ha (green weight) after 2 years of closure to 7487 kg/ha (green weight) after 4 years of closure. It also appears that the maximum rate of production was reached 3 to 4 years after closure specially in ravine bottoms, which are in a higher state of productivity (Kaul, 1962a).

For various reasons closures seem to be the only effective method of improvement of degraded grasslands in India in the initial stages. It has, however, to be agreed that it is difficult to effect closures, but at the same time they are absolutely necessary.

2. *Reseeding*

Reseeding is probably the quickest and the surest method of improving degraded grasslands. Though little experimental evidence is available under Indian conditions on this important subject but choice of species, quality of seed, soil preparation, method of sowing, seed rate, soil moisture conditions, are some of the factors to be considered for successful reseeding.

Reseeding of grasslands with seeds of highly palatable grass species suitable to the soil and rainfall conditions has given very encouraging results in Rajasthan. The increase in yield (air dried forage) in seeded over natural strips for 'excellent', 'good', 'fair' and 'poor' condition grasslands was 254, 86, 94 and 30 per cent respectively. There was substantial increase in forage production in 'excellent', 'good' and 'fair' condition grasslands (Anonymous, 1964).

The selection of grass seeds to be reseeded has to be carefully made. In arid and semi-arid parts (*Dichanthium-Cenchrus-Elyonurus* grass cover) reseeding could be done with seeds of *Cenchrus ciliaris*, *C. setigerus*, *Lasiurus sindicus* (*Elyonurus hirsutus*) and *Panicum antidotale*. The

II—Improvement Measures

The most important phase in the improvement of animal nutrition is the development of grazing and fodder resources by managing and utilising the grasslands properly and by increasing the fodder from cultivated lands. Unfortunately, as mentioned earlier, many of the grasslands in Rajasthan (as in other parts of the country) have so badly deteriorated due to excessive grazing, overstocking and improper management practices that simple adjustments in management practices are not sufficient and other improvement measures have to be adopted. Depending on the condition of the grasslands (for condition classification see Dabadghao, 1958; Bhimaya & Ahuja, 1967), improvement measures for forage production may vary from simple closure to reseeding the area with better grasses, soil and water conservation measures, use of fertilizers, control of weeds, etc., which are described hereafter.

1. Closures

Ecological management or closure followed by regulate dgrazing is an important method for the improvement of degraded grasslands as it induces progressive succession. Grasslands in India seem to have a remarkable capacity for rapid regeneration after closure from serious misuse. Regeneration which usually occurs within 3 to 5 years may be accelerated by other cultural operations, i.e., removal of weeds, soil working, planting, etc.

The rate of progression towards production of superior grass cover would, however, depend on the condition class of the grassland including the species present to provide a seed source and the rainfall. Studies carried out in western Rajasthan (Anonymous 1964) have shown that with proper management and controlled grazing *Lasiurus* and *Dichanthium* come up naturally in the course of succession. 'Poor' condition grasslands can be upgraded to 'fair' ones in 3 to 5 years in areas with a rainfall of over 375 mm and in 5 to 7 years in lower rainfall tracts (below 375 mm). Accordingly, 'fair' condition grasslands can be upgraded to 'good' grasslands. In another study carried out in different types of grasslands in the desert region of western Rajasthan, with closures and different grazing treatments, grass cover substantially improved during the period 1960-1963. The increase in air dry forage production during this period, in 'poor', 'fair', 'good' and 'excellent'

transplanting or rooted slips; *Cenchrus ciliaris* and *C. setigerus* have given good results with both methods (Whyte, 1964; Kaul, 1962). Line sowings of *C. ciliaris* and broadcast sowings of *Lasiurus sindicus* are reported to have given better results (Chakravarty *et al.*, 1966). Recommended mixtures of seeds to be sown in arid areas of Rajasthan by different rainfall zones and soil types have already been mentioned. The seed rate recommended on the average is about 6 kg/ha. Unhusked grass seeds are taken and thoroughly mixed with three to four times their volume of moist sand or soil on the sowing day. Such mixture of seeds and moist soil enables uniform sowing of seeds in furrows. Further studies on reseeding in Rajasthan (Gadra Road, Bikaner and Pali—rainfall below 125, 250 and 400 mm respectively) have shown the effectiveness of harrowing where *Cenchrus ciliaris* and *C. setigerus* were more successful than *Panicum antidotale*.

Though reseeding after the outbreak of the monsoon is generally met with success, an experiment (Jodhpur) which compares the time and method of reseeding depleted grasslands has shown that premonsoon sowing with harrowing are also effective. The success of these premonsoon sowings open up the possibility of undertaking dry sowings thereby increasing the period of sowing, making it possible to undertake reseeding on large areas (Anonymous, 1962; Whyte, 1964).

It has been recommended that no grazing should be done during the first year of establishment after reseeding and light grazing during the second year, if the stand is fairly good, may be done from October onwards. From the third year of establishment moderate grazing (60 per cent utilisation) after the first week of August is recommended. Rotational grazing should be practised during the grazing season to allow the grasses in each compartment to put on fresh growth each time (Ahuja & Bhimaya, 1966).

3. Soil and Water Conservation

Soil and water conservation measures in dry and arid areas become an essential part of a grassland improvement programme where grasslands have been deteriorated. The type of conservation measures to be undertaken, however, would depend mainly on the condition of the area, topography, slope, rainfall, etc. etc. Critical areas and slopy lands where water erosion is active causing gully formation (e.g., dry areas in

establishment and performance of *Lasiurus sindicus (Elyonurus hirsutus)* has been highly impressive in sandy soils and low precipitation zones. *Cenchrus ciliaris* and *C. setigerus* perform well with an annual rainfall of 150-750 mm on wide range of edaphic conditions. *Dichanthium annulatum* occurs naturally on heavier soils with higher rainfall and gives good performance in areas of over 400 mm rainfall (Ahuja & Bhimaya, 1966). Successful introduction of *Dichanthium annulatum* on degraded ravine watersheds near Kota has also been made (Kaul, 1962). Ahuja and Bhimaya (1966) have suggested a mixture of grasses for reseeding grasslands in Rajasthan, as given in Table 1.

Table 1—Mixture of grasses suggested for reseeding grasslands in Rajasthan (Ahuja & Bhimaya, 1966).

Medium rainfall Annual rainfall above 380 mm		Low rainfall Annual rainfall below 380 mm	
Heavy soils	Light soils	Heavy soils	Light soils
Dichanthium annulatum & *Cenchrus* spp.	*Cenchrus* spp. & *Lasiurus sindicus*	*Cenchrus* spp. & *Dichanthum annulatum*	*Lasiurus sindicus* & *Cenchrus* spp.

Reseeding may be done on level soils in rows 45 cm apart but the distance may be increased, if necessary, depending on seed stock, economics of reseeding, the urgency of revegetation of grassland, etc. In areas subject to wind erosion reseeding may be done in strips at right angles to the direction of the wind. Soil preparation may be in the form of light harrowing, making of contour furrows or contour trenches etc. etc. depending on topography and soil, and sowing would be done along these contour furrows or trenches. Ahuja & Bhimaya (1966) in their reseeding work in Rajasthan mention that grass seed mixtures should be sown in furrows 75 cm apart at the end of June or after the first effective shower. The furrows should be shallow (less than 10 cm deep) and the seed should be covered not more than 2 cm with soil.

Preliminary experiments on the method of propagation of grasses carried out in Rajasthan indicate that *Lasiurus sindicus (Elyonurus hirsutus)* and *Panicum turgidum* can be established by direct seeding, while *Panicum antidotale* and *Dichanthium annulatum* are best established through

Water spreading in grasslands has not received much attention in India so far. It has, however, been tried on a very limited scale in Rajasthan on pasture development area at Samadari where the runoff from a rocky hill collects and forms seasonal streams which cause serious gullying in the lands below. The area benefited is about 4 hectares (Whyte, 1964).

4. *Use of Fertilizers*

The possible use of fertilizers to increase production and thereby improve the condition of the grasslands has evinced considerable interest in the recent past. Though there is not much experience to guide, increase in yield as a result of fertilizers has been reported from different parts of the country. Probably the most spectacular example of increased yield of grass by fertilization is at the Araey Milk Colony in Bombay, where *para* grass gave 224,170 kg/ha of fodder when given cow-shed wash, while with ordinary irrigation water it yielded 112,085 kg/ha of green fodder (Anonymous, 1956).

As regards grasslands in Rajasthan, fertilizer applications have caused increased yields of grasses. In Mendra Bir (Bharatpur) increased yields of 3.5, 7.9 and 16.2 per cent with application of ammonium sulphate nitrate, single super phosphate and mixture of both at 112 kg/ha respectively were observed (Anonymous, 1968). Studies conducted at Jodhpur on the effect of several manurial treatments on the production and nutritive value of certain grasses like *Lasiurus sindicus (Elyonurus hirsutus)*, *Cenchrus ciliaris*, *C. setigerus* and *Panicum antidotale* have indicated that in general application of nitrogen either singly or in combination with phosphorus or phosphorus and potash gave favourable and significant response in all desert grasses (Dabadghao *et al.*, 1965). Ahuja and Bhimaya (1966) mention that high yielding grasses with fairly high protein content respond well to commercial fertilizers. Application of ammonium sulphate at 112 kg/ha in a single dose on a rainy day has given increased yield of air dry forage by 48, 69, 33 and 46 per cent in 'poor', 'fair', 'good' and 'excellent' condition grasslands. In 'good' and 'excellent' pastures response to application of 22.4 kg of N and 22.4 kg of P_2O_5 were economical (Anonymous, 1964; Ahuja & Bhimaya, 1966).

The application of fertilizers to natural grasslands in the country as a whole, however, does not appear to be an economic proposition

Kota) small check-dams of brush, loose rock, poles, etc. etc. across the drainage channels may be necessary; a number of small check-dams being preferable to a few large ones.

Where water is a limiting factor the principal object of the improvement programme is to retain as much moisture as possible on the grassland to favour grass growth. These conservation practices would also be useful in reseeding of grasslands as rainfall is normally insufficient in these dry areas to permit seedling establishment. Simple harrowing, contour furrows, soil pitting and soil ripping, etc. are some of the practices which can be adopted. Contour furrows are effective on gentle to moderate slopes but have to be properly designed.

Soil pitting would consist of digging a series of long narrow staggered pits across the slope on the grassland. They amount to short interrupted contour trenches or furrows and can be used on lands that are too uneven for contour furrows. The increased moisture retained in the pitted surface would give better forage thereby increase the carrying capacity of the grassland. It has been reported that contour furrows, contour bunds and contour trenches in grasslands with shallow soils have resulted in increase of forage by 96 per cent (683 to 1338 kg/ha) in Rajasthan (Anonymous, 1964). Soil ripping would be necessary in grasslands with heavy soil (Pali area) where water absorption is slow. Breaking of the ground under such conditions would increase moisture penetration and forage production. Ripping has to be done to a depth that will break the shallow hard pan layer below.

The utilisation of rain water for the improvement of grasslands in dry and arid areas through water spreading (Stokes *et al.*, 1954), which is a simple form of flood irrigation accomplished by diverting runoff from natural water courses and spreading the flow over adjacent areas needs mention. In recent years water spreading in grasslands has assumed importance as it improves the productivity of the grassland (thereby increase the carrying capacity of the area) and lengthens the growing season during which the forage is succulent and nourishing, because of the extra moisture available. Water spreading, though used in many grasslands, could not be used everywhere as the sites have to be selected with great care giving due consideration to topography, climate, soil, available water supply, present and potential vegetation of the area, etc.

species in this respect. This species is being grown (125 to 150 trees per hectare) by the farmers in their fields in the desert region where crop growth is reported to be better in fields with scattered trees of *Prosopis spicigera* (Pathak, 1958).

Top feed species are of prime importance in supplementing livestock requirements in arid regions, especially as they supply feed at a time when very few grasses or forbs occur in the grazing lands. These top feed species also upgrade the carrying capacity of otherwise poor grasslands. Studies carried out in Rajasthan have shown that from the point of view of palatability, nutritional status and ready availability, *Prosopis spicigera* and *Zizyphus nummularia* are the best top feed species for cattle, sheep and camels, while *Calligonum polygonoides*, *Salvadora oleoides*, *S. persica* and *Gymnosporia spinosa* constitute an important source of leaf fodder for camels (Ganguli *et al.*, 1964). Suitable spacing of the tree species in the grasslands has, however, to be worked out.

6. *Control of Weeds*

Herbaceous and woody perennial weeds like *Tephrosia purpurea*, *Aerua tomentosa*, *Xanthium*, *Cassia tora*, *Calotropis* spp., *Crotolaria burhia*, etc., are very common in the degraded grasslands of the State and their removal is one of the most important steps towards grassland improvement to remove any competition with better grasses. Competition from unwanted growth is rather acute in these dry and arid areas due of lack of moisture and rather spectacular results have been obtained with proper weeding carried out at the proper time. Of the various methods of controlling weeds like uprooting, cutting off at the ground level, mechanical means, burning and application of weedicides, uprooting of weeds manually before they form the seed is the commonest method used at present. Shrubs and tree sprouts can be best controlled by cutting them at the proper time. Sheep and goats also help in keeping down some of the weeds (goats would eat even *Calotropis*) and it may be desirable to have a few sheep and goats with cattle on the pasture. No power equipment has so far been used in this country for mechanical weeding in grasslands.

Though weedicides offer a great promise for effective weed control on grasslands, their application on any scale has not yet been undertaken in this country mainly because of their high cost and finding out a

to be adopted on a wide scale. This has also been indicated by some of the manurial trials made with certain desert grasses at Jodhpur (Dabadghao *et al.*, 1965) and in the ravine grasslands of Gujarat where application of fertilizers to grasslands has increased grass yields but have proved to be uneconomical. Fertilizers are badly needed for raising agricultural crops which have to be given top priority, and they involve considerable expenditure which could only be justified with a high producing livestock. Further, there have been very few field trials conducted in various regions of the country with regard to the application of fertilizers to natural grasslands, which would give an indication of the actual increase in yield by using fertilizers, the circumstances under which such increases would take place and their extent.

The possibility of using town sewage at selected places for the production of high quality green feed needs mention as this constitutes an enormous waste of this source of fertility. It has been reported that in Coimbatore yield of 392,300 kg (green)/ha per year is being obtained from Guinea grass irrigated with town sewage (Whyte, 1964). Though town sewage is being utilised at some places in the country, its use on an extensive scale has yet to find a place.

5. *Windbelts, Fodder and Shade Trees*

One other measure of grassland improvement in the arid zone is the creation of windbelts around grasslands. Windbelts have primarily the same function on grasslands as on farm lands, i.e. to protect the areas from wind erosion and to increase the quality and quantity of grass yield by creating better soil and microclimatic conditions. Though there are no data to illustrate this increase from India, examples of increased forage yields have been reported from several other countries (Caborn, 1957; Stoeckeler, 1962; Eimern *et al.*, 1964; Read, 1964).

Shade is an important factor in grassland management and needs to be provided on all grasslands where air temperatures are high. Besides the shade provided by the windbelts, it would be necessary to have some trees well distributed in the grasslands, which would provide shade to the cattle and at the same time be useful as fodder (top feed species). Besides checking wind erosion these scattered trees would also bring about a change in the microhabitat creating favourable condition for succession of perennial grasses. *Prosopis spicigera* is a prized

III—RESEARCH AND DEVELOPMENT

Though correct animal feeding has been repeatedly stressed as being essential it has received very little attention in the past in this country. There is, however, no doubt that research and development on the grassland and fodder resources of the country have gained considerable momentum during the last decade or so. The recognition of different grass covers of India has been a landmark for planning grassland improvements. The results of the survey have also revealed that most of the high potential grazing land of the country are situated in the arid and semi-arid zones of India. Considerable amount of work on various aspects of grassland management and improvement in dry and arid areas of Rajasthan has since been done by the Central Arid Zone Research Institute, Jodhpur, and the State Forest Department. The most significant development in the recent past has been the establishment of Indian Grassland Research Institute at Jhansi. With all these research and developmental activities and the various grassland improvement schemes that the State Government has launched, the next decade should see important developments in the management and improvement of grassland in Rajasthan and the country as a whole.

IV—SUMMARY

The problem of animal nutrition is of great intensity arising out of the very high livestock population of the State which has resulted in progressive deterioration of the grazing land and severe soil erosion, providing only below subsistance feed to livestock which in turn is reflected in their poor yield of milk, wool and meat.

Reconnaissance surveys have indicated a high potential of such nutritionally important and palatable grasses like *Lasiurus sindicus (Elyonurus hirsutus)*, *Cenchrus ciliaris*, *C. setigerus*, *Dichanthium annulatum* and *Panicum antidotale*.

The paper discusses the various grassland improvement measures in dry and arid tracts of Rajasthan, which may vary from simple closure to reseeding the area with better grasses, soil and water conservation measures, use of fertilisers, windbelts and control of weeds, citing the results of various studies conducted so far with regard to different improvement measures.

suitable weedicides for application. Weedicides like 2, 4-D and 2, 4-5-T, and other related compounds have been extensively used in other countries to kill weeds, broadleaved shrubs and trees *(Prosopis)* on grasslands in arid areas (Cable & Martin, 1964; Kaul, 1965). Some trials with 2, 4-D, 2, 4-5-T and a mixture of both (spontox) in appropriate concentrations were undertaken in Rajasthan and these chemicals have been reported to be effective on shrubs and even trees have been killed (Ganguli, 1964).

Mention needs to be made of the fodder potential of *Zizyphus* and other tree and shrub species (*Prosopis spicigera, Capparis decidua,* etc.) found in the grassland of the State which are otherwise to be constituted as weeds. Some of these shrub and tree species are a valuable source of fodder of which *Zizyphus* is the most important. Its leaves (locally called *pala*) are rich in protein (crude protein content of leaves varies from 14.24, 14.62 and 14.70 per cent in monsoon, summer and winter respectively) and are used as supplemental feed for milch cattle. Leaf fodder of *Zizyphus* also remains abundantly available when all other grasses have dried up. As such this species plays a vital role in increasing the carrying capacity of these otherwise depleted grasslands. Besides these bushes check wind erosion and bring about a change in the microhabitat causing better grasses to come in, thereby upgrading the deteriorated grasslands. Besides its fodder potential, *Zizyphus* thorns are the only source of fencing of these grassland and have high calorific value as fuel.

In view of the high fodder potential of *Zizyphus* there is thus a need for maintaining a proper density of both grasses and *Zizyphus* in order to have the right proportion of *Zizyphus* to obtain maximum forage yield per unit area. Working on 11, 14, and 18 per cent densities of *Zizyphus* in a grassland, Kaul and Ganguli (1963) found that the average total forage yield per hectare corresponding to the three densities of *Zizyphus* was 695, 1,000, and 875 kg respectively. Density of 14 per cent also gave the highest yield of grass (875 kg) per hectare. Densities higher than 14 per cent suppressed the production of grass in the pasture.

Among other improvements of grasslands, control of range destroying rodents which are very common in the desert needs to be looked into.

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GRASSLANDS AND RANGE RESOURCES STUDIES OF SHEKHAWATI AREA, RAJASTHAN

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(With 2 Tables)

I— Introduction

' The universality of occurrence and beneficence of grasses is well known and is something to be reckoned with. A glance at the available literature on the subject reveals meagre and fragmentary information about the same. The main contributors are: King (1879), Duthie (1886), Blatter and Hallberg (1918-21), Mahabale and Kharadi (1946), Sarup (1951, 1954, 1957 and 1958), Sarup and Vyas (1951), Krishnaswamy and Gupta (1952), Biswas and Rao (1953), Bakshi (1954), Nair (1956, 1961), Nair and Nathawat (1956), Ratnam and Ramdeo (1957), Nair *et al.* (1958), Satyanarayan (1958a, b), Joshi (1958), Jain *et al.* (1960), Sharma (1961, 1962, 1965, and 1968), Mulay and Mathur (1961), Vyas (1962, 1962-63, 1963, 1964, 1965 and 1967), Jain (1962), Raizada and Sharma (1962), Vyas and Gupta (1963), Satyanarayanan (1963), Bhimaya *et al.* (1964), Cherian and Gaur (1965), and Raheja (1965).

Various aspects of grasses have been worked out by Mulay *et al.* (1955), Mulay and Leelamma (1956), Vyas (1964), Sarma (1965) Kanodia and Rao (1965, 1965-66), Chakravarty and Verma (1965) and Chakravarty and Kulkarni (1966).

Joshi and Sarma (1966) published a list of grasses of certain areas in Jhunjhunu district. Information regarding range resources of Rajasthan have been given by : Satyanarayanan (1958), Prakash and Nanda (1961), Kanodia and Rao (1362-63), Das *et al.* (1963, 1964), Misra and Das (1963), Das (1964), Das and Gupta (1964), Prakash and Ahuja (1964), Shankaranarayanan and Satyanarayanan (1964), Chakravarty (1965), Chakravarty and Das (1965), Dabadghao *et al.* (1965), Kaul (1965), Lahiri and Kharabanda (1965), Shankaranarayan *et al.* (1965), Vyas and Gupta (1965), Ahuja and Bhimaya (1966), Chakravarty and Kulkarni

2. *Biotic Factors*

Termites, locusts, common birds like peacocks, patridges and pigeons, and livestock are the main biota which influence and damage the grass cover at various stages of its development. The data below give the area and live-stock population of the two districts :

District	Population, 1971 Census
Jhunjhunu	921,637
Sikar	1,039,603
Total	1,961,240

Total livestock population (according to livestock census, 1961)	8,06,000
Total area (in thousand acres) under fodder crops (figures taken from Agriculture Situation in India, Sept. 1959)	3,756
Ratio of total livestock population & area under fodder crops	215 : 1

3. *Edaphic Factors*

Due to eroded physiography and perpetual shifting of dunes the soils mostly are sandy and azonal. The loose sandy soils of the plains, embryo, barchanoid and longitudinal ridged dunes are all formed of blown sand. The sandy soils have a single grain structure, are very porous and thus readily permeable. The round, minute sand particles facilitate good drainage and percolation due to good aeration but also help in 'sheet erosion' during summer months. For different ranges of soil particles in different areas refer to Table 1.

Table 1.—Area-wise ranges of soil particles

Depth at which samples were taken	Mechanical nature			
	% of Fine Gravel	% of Coarse Sand	% of Fine Sand	% of Silt & Clay
1. Low lying areas				
Surface	7 0	8.5	75 0	9 5
10 0 Cm.	2.5	7.4	81 5	8 6
20.0 Cm.	4.4	8 4	81.2	6 0
30.0 Cm.	6 0	5.4	79.8	8.8
2. Sandy and dune areas				
Surface	0 25	8.2	87 8	3.75
10.0 Cm.	0 00	8.4	86.1	5.50
20 0 Cm.	0.10	6.9	92.5	1.40
30.0 Cm.	0.10	8.2	88 0	3 70
3. Hilly areas				
Top	9.50	61.5	16.3	12.70
Middle	6.50	77.0	11.5	5 00
Base	4 00	69.5	14.7	11.80

(1966), Chakravarty *et al.* (1960), Gupta and Saxena (1966), Malhotra (1966), Sen (1966), Jain (1967), Ahuja and Bhimaya (1967), and Satyanarayan and Gaur (1967).

The present paper analyses the existing grasslands and range resources problems of the Shekhawati region in Rajasthan.

II—PHYSIOGRAPHY

Shekhawati, situated between 27° 9′ and 28° 37′ N latitudes and 74° 43′ and 76° 9′ E longitudes, consists of two northernmost districts of Jhunjhunu and Sikar. The total area of Shekhawati comprising the two districts (Jhunjhunu : 5900 sq. km. and Sikar : 7700 sq. km.) is 13600 sq. km. Thus, in area Jhunjhunu is the smallest district of Jaipur division, and Shekhawati as a whole represents a little over one-fifth of the area of this division.

Areas in Shekhawati are covered by wind blown sand and dunes. The rugged hills, saline and aquatic areas are other habitats of the region. The landscape presents an irregular topography. The terrain is not altogether flat as there are chains of hills, and scattered, isolated outcrops of rocks at many places except the north-western desert portion. Harshanath (3,000 ft. above M.S.L.), situated at 27° 37′ N and 75° 8′ E, is the highest peak near Sikar. The Aravalli hill ranges of Singhana and Khetri lie at 28° N and 75° 51′ E. The following ecosystems are recognised within the area : 1. Rocky; 2. Aquatic and marshy; and 3. Sandy plains and dunes. The only river of importance in this area is Katli. This and a few other minor streams are all rainfed and are soon lost in sands within the outlines of Jhunjhunu and Sikar districts.

III—ENVIRONMENT

1. Climatic Factors

The climate of the area is semi-arid, typical of many other regions of Rajasthan. In general the area is characterized by extremes of temperature and low rainfall. Diurnal variation in the day and night temperatures is always large. The month of June has the highest maximum temperature (44°C) while January shows thelowest minimum (1°C). Rainfall is maximum in July or August (100-300mm).

The soils in general are sandy and possess low fertility, while the soil found in Khetri, Udaipurwati and Sikar are sandy and sandy loam and are comparatively more fertile. Water is available at 100 to 120 ft. depth in Jhunjhunu and 20 to 40 ft. in Khetri and Udaipurwati.

IV—GENERAL ASPECTS OF GRASSLANDS

On the basis of their water requirements, the grasslands growing in Shekhawati region can be grouped under the following categories :

1. *Rainy season grasses* : Behave like ephemerals.
2. *Off season grasses* : Appearing in late winter and before summer. Common to category 1 above.
3. *Perennating grasses* : Discard aerial parts during unfavourable season and appear again whenever suitable conditions set in.
4. *Perennial grasses* : Remain throughout the year.

The grass cover worked out in the area has been classified according to their habitat preferences, seasonal, fodder value, stabilization and afforestation aspects, and drought tolerance.

1. *Annuals*

These include *Apluda mutica* L., *Bothriochloa ischaemum* (L.) Keng., *Cenchrus biflorus* Roxb., *C. prieurii* Kunth., *Digitaria adscendens* (H.B.K.) Henr., *D. sanguinalis* (L.) Scop., *Echinochloa colonum* (L.) Link., *E. crus-galli* (L.) P. Beauv., *Setaria verticillata* (L.) P. Beauv., *Polypogon monspeliensis* (L.) Desf., *Aristida mutabilis* Trin. et Rupr., *Chloris prieurii* Kunth., *Melanocenchris jacquemontii* Jaub. et Spach., *Tetrapogon tenellus* Roxb., *Acrachne racemosa* (Heyne) Ohwi, *Dactyloctenium aegypticum* L., *Eragrostis ciliaris* (L.) R. Br., *E. poaeoides* P. Beauv., *E. tenella* (L.) P. Beauv., *E. tremula* Hochst., *E. unioloides* Retz., *Poa anuua* L., *Perotis hordeiformis* Nees, *P. indica* (L.) O. Ktze., *Sporobolus coramandelianus* (Retz.) Kunth. and *Tragus biflorus* Schult.

2. *Perennials*

These include *Bothriochloa pertusa* (L.) A. Camus, *Cymbopogon martinii* (Roxb.) Wats., *C. parkeri* Stapf, *Heteropogon contortus* (L.) P. Beauv., *Saccharum bengalense* Retz., *Cenchrus ciliaris* L., *Panicum antidotale* Retz., *Chloris barbata* Sw., *Cynodon dactylon* (L.) Pers., *Dactyloctenium*

of animal feed at the appropriate times of the year to maintain its livestock population. Therefore, grassland survey and study of fodder grasses and its other economic aspects is important. Chakravarty (1961), has worked out the dominant highland grass species which add to the bulk of production. He has found that the productivity reading comes to about 51,000 pounds of green fodder per acre. The same author has obtained about 44,000 pounds of green fodder per acre from the low land grass trial by six cuts annually.

Shekhawati region has a low annual rainfall which is erratic. Winter rains are of rare occurrence. Evapotranspiration exceeds precipitation. Under such intense conditions of high temperature variations and extremes the grass cover remains for a comparatively short duration of time. The productive grasslands are soon subjected to indiscriminate and unrestricted grazing everywhere by large herd of sheep, goat and domesticated cattle. The onslaught on grass cover in particular goes on relentlessly resulting in many barren and denuded areas again. In spite of the intense biotic pressure, the growth of grasses under stress makes their vulnerability and susceptibility to biota less recognizable. The livestock, which browse and graze on all fodder grasses, are considered indispensable and, therefore, should be maintained in fenced areas. These, if protected, are seen to grow well with their tenacious fibrous roots which hold the soil. The period of their appearance, growth and development seasonally and annually will definitely help in ameliorating the conditions in the area. It has been shown at the Central Arid Zone Research Institute, Jodhpur, that a range land adequately protected from unauthorized grazing by proper and effective fencing and allowing grazing at a controlled rate, based upon the grazing capacity of the range, doubles its production within three years. Grass cover in fenced areas will thus protect soil better from erosion. This will help in increasing soil fertility by retaining humus and also aid in soil binding and more water holding capacity. This naturally will result in high carrying capacity with most efficient rooting and spreading behaviour of grasses present in the area.

The distribution of characteristic natural fodder grasses in different ecosystems of Shekhawati, is basically controlled by effective precipitation, topography and soil condition. As such grasses from eroding areas could be saved from biotic exploitation to help in building up the

sindicum Boiss., *Desmostachya bipinnata* (L.) Stapf and *Eragrostis riparia* (Willd.) Nees

3. *Fodder*

These are *Apluda mutica* L. (when young), *Bothriochloa pertusa* (L.) A. Camus, *Sorghum halepense* (L.) Pers., *Brachiaria ramosa* (L.) Stapf, *Digitaria adscendens* (H.B.K.) Henr., *D. sanguinalis* (L.) Scop., *Echinochloa colonum* (L.) Link., *Acrachne racemosa* (Heyne) Ohwi, *Tragus biflorus* Schult., *Cenchrus* and *Eragrostis* spp.

4. *Sand Binders*

These include *Panicum antidotale* Retz., *Dactyloctenium sindicum* Boiss., *Desmostachya bipinnata* (L.) Stapf (excellent sand binder), and *Saccharum bengalense* Retz.

5. *Drought Resisting*

These are *Chrysopogon gryllus* (L.) Trin., *Cenchrus biflorus* Roxb., *Panicum antidotale* Retz., and *Bothriochloa pertusa* (L.) A. Camus.

V—DISCUSSION

The interdependence of plants (especially grasses) and animals (including man) is universal. This inter-relationship becomes of paramount importance in arid and semi-arid regions where the low plant cover is mostly rain-fed and quite sparse in the off season. The balance between the vegetation and biota is, therefore, to be maintained to avoid extension of denuded habitats in such areas. Shekhawati, like other regions of Rajasthan, has also been subjected to intense and unrestricted grazing and biotic exploitation resulting in sparse plant cover. The rainy season herbs and grasses are wiped out and badly damaged at all stages of development within a very short interval of time by the herds of domestic cattle, sheep and goat. The problem, therefore, needs careful thinking, planning and utilization of range resources on sound ecological principles based on thorough field studies.

Recently, Whyte (1957) suggested that the livestock farms in India should be laid out in such a way as to provide the amount of grazing land, hayland, and cultivated land necessary to yield sufficient quantities

should be worked out before any clear picture can emerge with regard to the range resources of the area. The average density of animals per hundred acres is 48 in Sikar and 50 in Jhunjhunu district (Statistical Atlas, 1959). The animals are allowed to graze on current fallows where the grasses are rich in nutrient content. The excessive grazing makes the regenerating capacity of grasses feeble.

The above information may be useful in planning the protective and productive function of grasses, and in selecting suitable grasses for range resources, fodder, protection of moving sand and in afforestation programme in Shekhawati. The economy of the area is based on its cattle, sheep and goat, hence improvement of range should be the paramount undertaking in Shekhawati region as its primary objective.

VI—SUMMARY

The universality of occurrence and interdependence of grasses is well known. The available literature on grasses and range resources reveals a sketchy information about the same. Only a few publications deal with grasses and range resources of Rajasthan, while hardly any work of significance has been done in Shekhawati area. The physiography, environmental factors and general aspects of grasslands in the area have been given. Problems connected with grass cover and range resources have been discussed. Steps have been suggested for ameliorating the conditions in Shekhawati. The information may be useful in planning protective measures and also in boosting the economy of the Shekhawati region.

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soil for *forbes* and for further suitable plants in stabilization processes. The grasslands in sandy areas of Shekhawati, therefore, can be developed for effective increase in organic matter in the soil which may further help in decreasing erosion and in improving soil fertility as also in having a favourable micro-climate.

At the same time production of grasses not preferred by cattle must be discouraged from spreading further. Protected areas could be reseeded with grasses of economic and fodder value with proper management and agronomic practices.

It has been observed that apart from the regular crops like *Pennisetum typhoides*, *Triticum aestivum*, *Zea mays*, etc., subsidiary starch food in famine has also been procured from grasses like *Eleusine indica*, *Echinochloa colonum*, *E. crus-galli*, *Digitaria sanguinalis* and *Setaria glauca*. The main fodder grasses are *Brachiaria ramosa*, *Bothriochloa pertusa*, *Echinochloa colonum*, *Eleusine indica*, *Dichanthium annulatum* and *Cenchrus ciliaris*, while oil can be procured from *Cymbopogon*. The other grasses of utility are *Saccharum*, *Bothriochloa pertusa* and *Heteropogon contortus* which are used for thatching of huts and cattle sheds.

Cattle, sheep and goat are the main wealth of Rajasthan and of Shekhawati too. Therefore, improvement of grasslands and range resources are of paramount importance since these feed the main animals of the area. This would not only save but boost the economy also of the Shekhawati region.

Sheep industry of Rajasthan is the largest in the country. The utilization of uacultivable waste lands with weeds by grazing and browsing by herds of sheep can go unhampered as sheep, unlike goat, does not damage tree growth. In fact the golden hoof of sheep bring prosperity to such areas by their droppings of dung which contain a high percentage of nitrogen and potassium. These 'four-legged fertilizer factories' enrich the soil and thus very much benefit the soil fertility and improvement.

Steps must be taken to grow grasses of medium fodder value but of great significance in sand stabilization too. In addition, more grasses could be added which, apart from their good forage value, have a high reproductive capacity. A complete information regarding the mesophytic, psammophytic and lithophytic grasses of the area is essential before assessing the grass cover's utility for the region. The productivity of grasses and population-land rationale and other aspects

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RANGE RESOURCES OF RAJASTHAN : A REVIEW

By

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(With 1 Table and 2 Text-figures)

I—Introduction

In Rajasthan, the main source of income of the rural population is livestock industry. The State is the largest wool producing zone in India (45% of the country's production). It has some of the best breeds of cattle, sheep and camel. According to the figures compiled by Whyte (1959, 1964) for the year ending 1956, there were 32,426,976 livestock in the State with 12,072,713 cattle, 3,439,449 buffaloes, 7,372,805 sheep, 8,730,163 goats, 303,579 camels, 303,579 equines, etc.

Livestock, being selective eaters, destroy better species and over-grazing eliminates finer grasses and shrub species. Lopping of trees by graziers further deteriorates the vegetational cover. Grassland problems in India, in general, have been discussed by Whyte, Venkataraman and Dabadghao (1954), ICAR Annual Report (1954), Guha, M.P. (1956), Whyte (1959), Dabadghao (1957, 1960, 1961), Rege (1962) and Puri (1966). Raheja (1962) has especially dealt with the research and development in the Indian arid zone.

II—Terrain

Western Rajasthan can be distinguished into three primary land-form regions (Bharadwaj, 1961) : (1) The predominantly sand-covered Thar, (2) Plains with hills including dune-free country, and (3) Hills. The secondary land-forms recognised are : (i) Plains with sand dunes, (ii) Plains of predominently older allumium, and (iii) Deltic plains. Geomorphology of granite landforms in the Indian arid zone has been described separately (Pandey, 1966).

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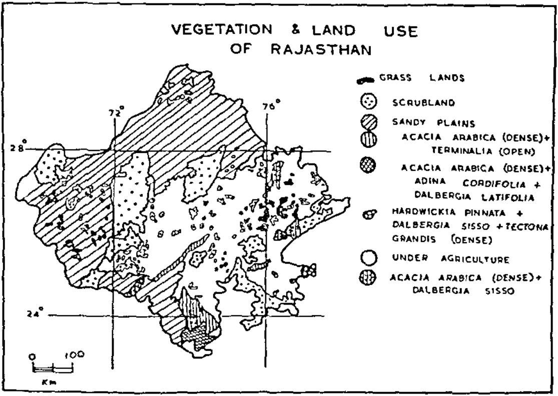
V—VEGETATION

According to the Survey General of India, total geographical area of the State is 84,576 acres; of which 3,553 is under forests, 14,833 acres is barren and uncultivable land, and 3,409 acres under permanent pastures and other grazing lands (*cf.* Text-fig. 2).



Text-fig. 2—*Vegetation and land use of Rajasthan (compiled from National Atlas).*

Ecoclimate of the State has carved out three vegetational zones, all of them along or parallel to Aravalli chain of hills :

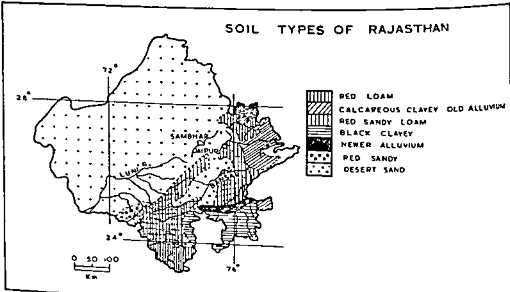
1. *Dry deciduous forests* : Mixed in nature and in which teak (*Tectona grandis* Linn. f.) is occasionally found to occupy south and south-east regions along Aravallis.
2. *Semi-arid region* : Some 1,600 km. across the line parallel to the first region. Here extreme xerophytes may occur.
3. *Arid region* : Comprising western Rajasthan; is the largest area.

III—CLIMATE

Climate of Rajasthan is arid in north-west and semi-arid in south-east portions. On the whole temperature is high and small rainfall causes the evaporation to exceed precipitation considerably. As a result there is insufficient moisture to promote good plant growth. Degree of aridity and humidity are indeed the main basis to explain the vegetation types (Meher-Homji, 1965).

IV—LITHOLOGY AND SOIL

Raychaudhuri *et al.* (1963) have given detailed description of Rajasthan soils. Rajasthan desert is a vast sandy plain with isolated hills or rock outcrops at places. Though, on the whole, the tract is sandy, soils improve in fertility from west and north-west to east and north-east. Many parts have saline or alkaline soils with unfavourable physical conditions and high pH value. The soils are structureless. Ground water is deep (Saksena *et al.* 1966). Soil types of Rajasthan are given in Text-fig. 1.



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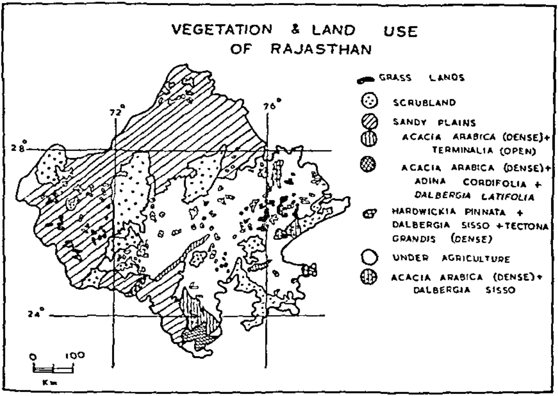

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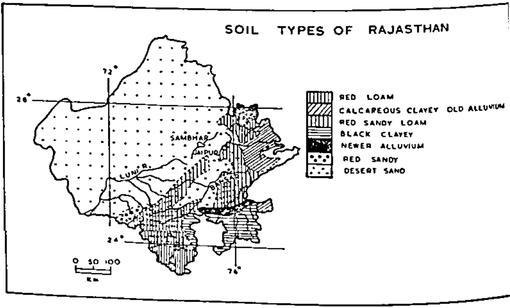

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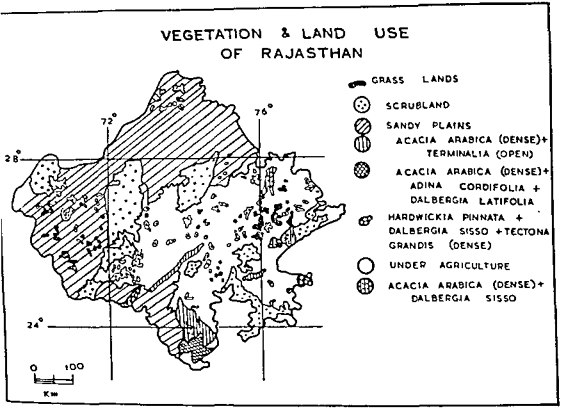

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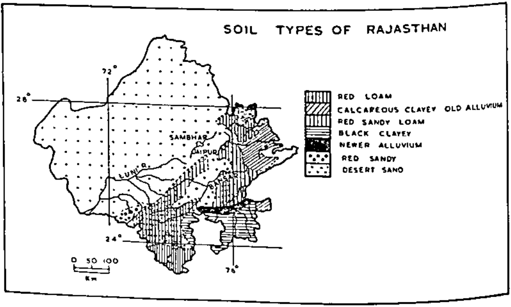

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in India and is associated with well known breeds of cattle. Soils underneath are sandy loams. Perennial grasses on such soils are : *Dichanthium annulatum, Cenchrus ciliaris, Cenchrus setigerus, Bothriochloa pertusa, Heteropogon contortus* and *Cynodon dactylon*. Annuals are : *Eragrostis* - several species, *Cenchrus biflorus, Aristida depresa, Dactyloctenium aegyptium* and members of the family Cyperaceae.

Dichanthium annulatum and *Cenchrus ciliaris* are the most important and dominant grasses. The grasslands are under heavy to close grazing by cattle and sheep and exhibit all stages of deterioration from gradual disappearance of the perennial species to sparsely populated annual grasslands, and ultimately to almost bare soils. During the process, soil undergoes severe erosion. The subclimax in the semi-arid tract is *Dichanthium annulatum* and is said to gradually eliminate *Cenchrus ciliaris*.

2. *Dichanthium - Cenchrus - Lasiurus Type*

These glasslands occur in the hilly arid tract of Jodhpur (Puri, 1960). Important perennials are : *Dichanthium annulatum, Cenchrus ciliaris, C. setigerus, Lasiurus hirsutus, Eleusine compressa, Cynodon dactylon, Sporobolus pallidus, Panicum turgidum* and *Heteropogon contortus*. Upon deterioration *Dichanthium annulatum* is suppressed and *Soprobolus marginatus, Cynodon dactylon* and *Eleusine compressa* begin to appear.

3. *On Sand Dunes*

In sandy arid areas, including sand dunes, sandy plains and sand hills, with drought and hot conditions vegetation is poor. Mobile sand dunes are least covered with vegetation. Leeward sides, being steep, are much more bare. Growth of vegetation is more and rapid on windward side. Pioneer plants on sand dunes are : *Calotropis procera, Leptadenia spartium, Indigofera urgentia, Aerua* sp. *Citrullus catocynthes*, etc. as the important forbs. Among grasses, *Panicum turgidum* and *Eleusine* sp. are little important from forage point of view. On fresh deposits of sands, *Aristida redacta, A. depressa* and *Cenchrus biflorus* grow well. Upon stabilization of dunes, the species are replaced by *Dactyloctenium sindicum* and *Eleusine compressa*. After about 10 years of protection, *Lasiurus hirsutus* attains complete dominance for a long time. On bunds, however, *Dichanthium annulatum* grows extensively. Raheja (1965) has divided the

Detailed work on the vegetation and ecology of these vegetational zones is not available. The only earlier account is by Blatter and Hallberg (1918). They recognised a) Sand Communities, b) Gravel Communities, c) Rock Communities, d) Ruderal Communities, and e) Aquatic Communities in Rajasthan.

According to Champion (1936), vegetation of Rajasthan is 'tropical thorny forests' or arid scrub forests, occuring in small scattered patches. Density and size of patches increase from west to east, closely following increase in rainfall and lesser evaporation.

Bharucha (1955) divided Rajasthan desert region in the following vegetation zones:

1. Area of shifting sand dunes, as at Jaisalmer and Bikaner.
2. Area of established sand dunes, as near Jodhpur.
3. Sandstone rocks covered by xerophytes like *Euphorbia nerifolia*.
4. Area of halophytic vegetation.

Common grasses in these regions are : *Aristida depressa, Cenchrus ciliaris, C. setigerus, C. biflorus, Cynodon dactylon, Desmostachya bipinnata, Dichanthium annulatum Eleusine indica, E. compressa, Dactyloctenium aegyptium, Panicum antidotale, P. turgidum, Sporobolus marginatus, Sehima nervosum, Eragrostis* sp., *Saccharum spontaneum, S. bengalense, Lasiurus hirsutus*, etc.

VI—RANGE RESOURCES

Dabadghao (1960) and Whyte (1964) have classified the grasslands of Rajasthan on rainfall basis. Three zones are recognised by them, viz. south and and south-east, semi-arid region with annual precipitation of 20 to 30 per cent; western and north-western plains with less than 10" (254 mm) rainfall; and the south-east portion with about 40" (1,016 mm) of rain. Grass communities vary in relation to topography and soil factor. The regions are as follows :

1. *Dichanthium - Cenchrus Type*

Semi-arid region is characterised by xerophytic thorny vegetation with *Zizyphus* sp., *Prosopis spicigera, Acacia* sp. and *Capparis decidua* as the dominant shrubs. Other bushy vegetation consists of *Tephrosia purpurea, T. villosa, Crotalaria medicaginea, C. burhia, Cassia occidentalis, C. auriculata* and *Calotropis procera*. The tract has some of the best types of grasses

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3. Sandstone rocks covered by xerophytes like *Euphorbia nerifolia*.
4. Area of halophytic vegetation.

Common grasses in these regions are: *Aristida depressa, Cenchrus ciliaris, C. setigerus, C. biflorus, Cynodon dactylon, Desmostachya bipinnata, Dichanthium annulatum Eleusine indica, E. compressa, Dactyloctenium aegyptium, Panicum antidotale, P. turgidum, Sporobolus marginatus, Sehima nervosum, Eragrostis* sp., *Saccharum spontaneum, S. bengalense, Lasiurus hirsutus*, etc.

VI—RANGE RESOURCES

Dabadghao (1960) and Whyte (1964) have classified the grassland of Rajasthan on rainfall basis. Three zones are recognised by them viz. south and and south-east, semi-arid region with annual precipitatio of 20 to 30 per cent; western and north-western plains with less than 1 (254 mm) rainfall; and the south-east portion with about 40" (1,016 m of rain. Grass communities vary in relation to topography and factor. The regions are as follows:

I. Dichanthium - Cenchrus Type

Semi-arid region is characterised by xerophytic thorny veget with *Zizyphus* sp., *Prosopis spicigera, Acacia* sp. and *Capparis decidua* dominant shrubs. Other bushy vegetation consists of *Tephrosia pu T. villosa, Crotalaria medicaginea, C. burhia, Cassia occidentalis, C. au* and *Calotropis procera*. The tract has some of the best types of

Under salinity at Pachbhadra, Sanwarla, Kanod, Biramsar, etc. halophytic plants are *Haloxylon salicornicum*, *Suaeda fruticosa*, *Zygophyllum simplex*, *Atriplex* sp. and *Tamarix dioica*. Conspicuous grasses are *Aeluropus lagopoides*, *Sporobolus marginata* and *Eleusine compressa*.

Ecological distribution of natural fodder grasses of western Rajasthan has been described byPrakash and Nanda (1961) on the basis of trends in succession and habitat types.

For the first time in Rajasthan, studies on different grazing and range management practices were initiated in 1959 by the Central Arid Zone Research Institute, Jodhpur, in order to rehabilitate the existing grasslands (Prakash and Ahuja, 1964). The investigations include an assessment of development of soil types under varying environs and being subjected to different intensities of grazing. For the study, 52 paddocks (each of 60 to 80 ha area) spread over ten districts of western Rajasthan and representing different soil types and rainfall zones belonging to various condition classes were chosen. Each paddock was subdivided into 4 or 6 compartments, and 'deferred' or 'deferred rotational' grazing was introduced. Depending upon the predominant perennial or annual grass species, these paddocks were grouped into four range condition classes, viz. excellent, good, fair and poor. These classes were grouped into 2 rainfall regimes : (a) high rainfall zone (above 380 mm) and (b) low rainfall zone (less than 380 mm), and were further divided into two main soil types (i) Light, and (ii) Heavy soils. The results show that the percentage of high perennials was higher in the grasslands classified as excellent or good (varying from 4.7 to 9.6 per cent according to rainfall), very low in grasslands classified as poor (varying from 0.4 to 1.4 per cent) and in between in fair grasslands (varying from 0.6 to 2.8 per cent).

Interesting results were obtained on grazing capacity studies at Pali near Jodhpur by the Central Arid Zone Research Institute, Jodhpur, during 1957-60 (Das *et al.*, 1963). Initially the grasslands were in poor condition and dominated by *Aristida* sp. During the experimental period, rainfall conditions were subnormal, normal and above normal respectively in the three years.

Mature Marwari wethers were grazed at 3.7, 6.5 and 8.1 sheep/ha in three successive years, respectively, on degraded pasture (dominated by *Aristida* sp., but bearing *Cenchrus*, *Eleusine compressa* and palatable shrub—*Zizyphus nummularia*) so as to give about 70% utilization. Over

State into four microclimatic regions or zones, six climax vegetation types and six grassland types within the climax vegetation types.

Zone I—Sub-humid : At Mt. Abu with annual rainfall exceeding 1,200 mm. Climax vegetation is *Mitragyna-Anogeissus* type. Chief grasses are : *Pennisetum hohenackeri, Eulalia trispicta, Themeda quadrivalvis, T. triandra, Dichanthium annulatum, Setaria glauca, Panicum maximum* and *Arthraxon hispidus.*

Zone II—Semi-arid : Eastern Rajasthan, with annual rainfall above 800 mm at Banswara and Baran regions, has teak *(Tectona grandis)* as the dominant species. Main grasses are *Themeda triandra, Pseudanthistiria heteroclita* and *Heteropogon contortus.*

Zone II B—With rainfall of 400 to 800 mm and reasonably good soil *Anogeissus pendula* is the dominant tree. The common grasses of the zone are : *Bothriochloa pertusa, Dichanthium annulatum, Cymbopogon jwarancusa, C. martinii, Chrysopogon fulvus, Sehima nervosum, Digitaria adscendens, Setaria glauca* and *Dactyloctenium aegyptium.*

Zone III—Ajmer, Pali and Sirohi to the west of Aravallis upto Jodhpur with annual rainfall of 450 to 500 mm forms the transition Zone III where the elements of eastern and western Rajasthan occur in association with each other. Here the vegetation gets thinner. Principal trees are *Anogeissus pendula, Acacia senegal, A. leucophloa, Prosopis specigera, Tecomella, Salvadora, Balanites,* etc. The grasses are : *Lasiurus hirsutus, Dichanthuim annulatum, Dactyloctenium sindicum, Cymbopogon jwarancusa, Aristida hirtigluma, Melanocenchris jacquemontii, Bragrostis ciliaris* and *Brachiaria reptans.*

The arid zone, on the extreme north-west, comprising Jaisalmer, Gadra Road, part of Barmer and part of Ganganagar, has annual rainfall of less than 200 mm and that too is very erratic. The zone is very sandy. There is paucity of species and only few can be observed dotting the landscape at considerable intervals. Notable among them are *Prosopis specigera, Acacia senegal, A. leucophloa* and *Tecomella undulata* with *Calotropis, Capparis, Lycium, Calligonum, Euphorbia neriifolia, Aerua,* etc. The grasses are *Lasiurus hirsutus, Eleusine compressa, Cymbopogon jwaranousa, C. parkeri, Aristida royleana, A. hirtigluma, A. mutabilis* and *Melanocenchris jacquemontii.*

3. *Resources survey of Nokha and Roda villages in Bikaner district* (Shankaranarayan, Pandey and Dhruvanarayan, 1965)

Surface and ground water resources, soils and soil erosion are described. The climate is arid, characterised by high temperature and erratic rains. The vegetation consists of open community of widely scattered trees of *Zizyphus nummularia* with sparse shrub cover and a seasonal growth of grassess and other herbs. Vegetational cover is 2.1% and the survey revealed the existence of *Dactyloctenium sindicum-Lasiurus sindicus* community. The present grasslands obtain 38 points and fall under poor range class. The main land-capability classes are IV, IV and V. There is no definite relationship between present land use and capability classes.

4. *Forage potentials of Jalore* (Gupta and Saxena, 1966)

Grassland types differ on different micro-geomorphic units. On hills *Sehima nervosum-Hackelochloa-Bothriochloa;* and on piedmont slopes and foot hills *Dichanthium-Eragrostis-Aristida* are the main grassland types; and on plains *Panicum turgidum* is the important grass. Basal cover of each grassland type was calculated by transect method. Air dry matter yield and average height of 22 grasses are given.

Findings on regional vegetations of Rajasthan are abstracted in Table 1.

VIII—OTHER FODDER

Besides grasses, Rajasthan has and can grow other species as fodder too :

1. Sinha and Dey (1956) have shown the suitability of the following legumes which can be grown in Rajasthan with profit : *Pueraria phaseoloides, P. hirsuta, Stizolobium cochinchinensis, Gliricidia maculata, Melilotus alba* var. *annua, Glycine javanica, Centrosema pubescens, Leucaena glauca, Trifolium repens* var. *ladino, T. incarnatum, T. hybridum, Alysicarpus vaginalis, Medicago hispida* and *Lotus corniculatus.*
2. Turnip and fodder beet grown under irrigation on sandy soil in semi-arid regions of Rajasthan during winters yielded 225-260 kg. of green matter/ha, which is more than from other fodder crops in the area (Patil and Krishna Rao, 1964).

the three years, *Aristida* sp., decreased from 71 to 55% and *E. compressa* and *Cenchrus* species increased by 8 and 5.5% to 27 and 11% respectively. Number of annual species decreased. Density of plant cover increased from 10 to 28%. *Aristida* species was grazed only after their awns dropped. Other species mentioned above were grazed fully until seed formation, when only the seeds were picked. *Z. nummularia* was grazed predominantly. Animals maintained their weights with seasonal variations. Average wool production was 100 g/head/yr. Over the whole grazing period (259-324 days) the animals gained 0.5 to 1.2 kg/head. Average grazing capacity was calculated at 6.17 wethers/ha (with 70% utilization); for long-term maintenance, however, grazing capacity is considered at 2.5 wethers/ha.

VII—REGIONAL STUDIES ON GRAZING RESOURCES

1. Grassland communities of Alwar (Vyas, 1964)

Following communities have been recognised on the respective habitat types :

i) *Bothriochloa-Aristida*	Dry hills
ii) *Heteropogon-Chrysopogon*	Hill slopes
iii) *Dichanthium-Cenchrus*	Rocky mixed substrata
iv) *Dendrocalamus-Saccharum-Vetiveria*	Moist valleys
v) *Cenchrus-Eragrostis-Dichanthium*	Sandy plains
vi) *Dichanthium-Cynodon*	Sandy loam plains
vii) *Saccharum-Cynodon-Eragrostis*	Sandy river bed
viii) *Arthraxon-Vetiveria*	Marshy places

2. Grassland types of river Luni basin (Shankarnarayan and Satyanarayan, 1964)

Five grassland types have been recognised :

a) *Sehima-Dichanthium*	Characteristic of heavier soils
b) *Cenchrus setigerus*	On sandy loams
c) *Eleusine compressa*	On lighter soils
d) *Cynodon dactylon*	On light to medium soils under irrigated conditions
e) *Aristida*	On skeletal and inhospitable soils

Nowhere in the tract the grazing lands are maintained in their optimum stage.

3. *Resources survey of Nokha and Roda villages in Bikaner district* (Shankaranarayan, Pandey and Dhruvanarayan, 1965)

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3. Herbaceous wild forms :
   a) *Alysicarpus rugosus*, *A. longifolius*, *Indigofera glandulosa*, *I. cordifolia*, *I. linifolia*, *Heylandia latebrosa* (all found in Rajasthan) are suitable fodder plants for drier regions. All these legumes deferred rotational grazing and seedling (Patil, 1957).
   b) *Alysicarpus rugosus* and several other species of the genus are capable of growing in association with valuable forage grasses.
   c) Bekaria *(Indigofera enneaphylla)* sheep grass is suitable for east Rajasthan (Patil, 1966). It is a perennial legume growing abundantly, on dry sandy overgrazed rangelands. It is palatable, has a prostrate growth habit, suitable for grazing by sheep and is prolific reed producer. It has a deep tap-root, thrives under grazing and competes well with annuals.
   d) Gandhi *et al.* (1966) have chemically analysed the plants of *Crotalaria medicaginea*, a common monsoonic herb of drier regions and used as fodder for camels. It shows a presence of upto 0.2% of a N-oxide base. The base occurs in a form which is less toxic than eastern form.
4. The phylloclades and fruits of the xerophytic shrub *Calligonum polygonoides* are used as fodder, reports Shaktawat (1961) from Bikaner. The shrub also checks soils erosion.
5. Results of Patel and Patel (1957) on fodder value of tree and vegetable leaves, suggest to harvest leaves of the following species as feed for cattle during winters : *Melia azadirachta* and *Tamarindus indica* have best nutrient content. Leaves of vines of some vegetable crops like *Crotalaria juncea*, *Ricinus communis*, and *Ipomea batata* have high protein, calcium and PO_4 during winters and could replace concentrates.
6. Kehar (1963), Ganguli *et al.* (1964), Whyte (1964) and Nanda (1967) have discussed the importance of top-feed species in supplementing livestock requirements in the arid regions. *Prosopis spicigera* and *Zizyphus nummularia* are classed as best top-feeds for cattle sheep and camels in arid Rajasthan, on the basis of their availability, palatability and nutritive value. They stand lopping. According to Ganguli *et al.* (1964) a

middle-sized mature tree of *Prosopis spicigera* yields about 45 kg of dry leaf forage (or loong). Likewise plants of *Zizyphus nummularia* growing in medium density (14%) at Jodhpur yields 125 kg of fodder per ha.

IX—FORAGE PRODUCTION

It is best to manage and maintain natural grasslands. For example in Saurashtra maximum yield of air dry forage in a reserved (fenced) plot was 3900 lb/ac and in grazed area it was only 570 lb/ac (Albertson, 1958). Likewise, Dabadghao (1954) has made some field trial in natural grasslands.

Raheja and Chopra (1959) have recommended the introduction of fodder crops into mixed farming creating fodder reserves and improving grassland. Recently Raheja (1966) has given exhaustive information for cultivating fodder crops and grasses, both during *kharif* and *rabi* seasons together with their yields on dry matter basis. Jain and Bohra (1966) and Chakravarty *et al.* (1966) have given some pasture establishment techniques. Many workers have pleaded for grass/legume mixtures for better yield. Thus Stitt (1958), Guha and Pandey (1960), Misra and Das (1963) and Davies (1965) have shown that the mixtures are good for pastures.

Response of desert grasses to fertilizer treatments is an interesting subject. Under Central Arid Zone Research Institute, at Central Research Farm, Jodhpur, four trials with 10 fertilizer treatments on *Lasiurus sindicus*, *Cenchrus ciliaris*, *Cenchrus setigerus* and *Panicum antidotale* were conducted over a period of five years. Grasses were established in the farm in 1958 and fertilizers applied in 1959. Results are presented by Dabadghao *et al.* (1965). The forage yield, which varied both with the type of fertilizer and the species, was very slightly higher in some treatment in some years. In some cases the growth under control was superior.

A profit and loss account of manuring has also been worked out by the authors from the forage production data on the basis of cost of fertilizers applied and the extra cost of forage obtained as a result of fertilizer application. The profit and loss account indicates that *none of the grasses could show an overall profit from any fertilizer*. According to the authors (*loc. cit.*), this may be due to two causes, viz. poor precipitation,

which might have acted as a limiting factor to the growth of plants and the set back to proper utilization of the fertilizer, and secondly due to application of fertilizers in small doses.

X—ECOLOGY OF GRASS SPECIES

Ecological studies on the native rangelands have revealed that intensity of rainfall and the soil type greatly influence the distribution of perennial grasses. *Lasiurus sindicus* is mainly confined to sandy soils and sand dunes in regions receiving a mean annual rainfall of 250-400 mm. *Cenchrus ciliaris* and *C. setigerus* occur on deep soils in regions receiving rainfall upto 250 mm and on a variety of soils in regions of higher rainfall. *Dichanthium annulatum* is confined to depressions in the low rainfall region (250-400 mm) and is more extensively distributed in regions where the rainfall is 400 mm and above (Kaul and Chakravarty, 1968).

1. *Root Studies*

Root ecology of some promising desert grasses of Rajasthan was worked out by Dabadghao *et al.* (1962-63). In a study of roots of 9 to 19 months old plants of *Lasiurus hirsutus, Cenchrus ciliaris, C. setigerus, Panicum antidotale* and *Dichanthium annulatum* the number of roots increased with age. *C. ciliaris* and *L. hirsutus* showed greatest percentage increase.

Recently, Chakravarty and Kacker (1967) have given the effect of spacing and cutting on root development of some promising desert grasses and legumes. Root elongation as well as development of fibrous roots in *Lasiurus sindicus* suffered due to cutting and closer spacing treatments. In *Cenchrus ciliaris* these treatments checked the root elongation but encouraged development of fibrous roots. Root nodulation of arid zone legumes has been studied by Satyanarayan and Gaur (1965).

2. *Cytology of Grasses*

Chromosome number, geographical distribution and taxonomy of *Dichanthium annulatum* were studied by Mehra (1961). Cytologically and morphologically he has distinguished varieties in the species. He (1963) has also distinguished and differentiated cultivated and wild *Eleusine* species into 4 distinct taxa : *E. indica, E. coracana*, Afro-asiatic types and

African Highland type, and *E. africana*, F.S.

On the basis of embryological studies Synder *et al.* (1955) has described the mechanism of apomixis in *Pennisetum ciliare (Cenchrus ciliaris)*. Embryology of *Eleusine indica* and *Dactyloctenium aegyptium* is also worked out (Chandra, 1968).

Histology of some desert grasses *(Cenchrus biflorus, C. prieuri, Cynodon dactylon* and *Saccharum munja, S. bengalense)* was investigated by Mulay and Saluja (1957).

3. *Grazing Studies*

The problem of pressure of grazing on native pastures in Rajasthan is indeed severe (Kumar, 1952). The destruction of vegetation by animals has been discussed, among others, by Prakash (1959). Effect of animal factor on soil conservation has been elucidated by Bhimaya (1961). Bhimaya *et al.* (1961) have given the total impact of human factor in relation to trees and shrubs in arid Rajasthan. Excessive grazing, cutting and burning has done very great harm, not only to plants but also to soil.

4. *Grasslands and Soil Conservation*

High evapotranspiration, and consequently very low effective precipitation, and severe grazing during the short vegetal growth has brought in extension soil erosion in Rajasthan. Indeed vegetation alone can check erosion and conserve soil.

Brief notes on some grasses and legumes useful for soil conservation in India were given by Dabadghao (1954). That the misuse of the grassland and fodder resources is the most important factor contributing to erosion in India is discussed by Whyte (1955). By removal of vegetation excessive runoff occurs leading to rapid erosion. He has suggested mixed farming under irrigation and rotational grazing of native pastures (see also Madan *et al.*, 1960).

Satyanarayan (1958) has given a review account of indigenous species in the stabilization of sand dunes in Rajasthan. The examples given are to function both as sand binders and fodder plants. Considering leguminous crops sown at different seed rates.

Gupta (1966) discussed causes of erosion in the arid regions and reviewed measures of conservation. Latter includes reduction in livestock

pressure, development of forage resources and sand dune stabilization. Information is also given on the botanical composition of rangelands particularly on species of forage value.

The pros and cons of wind-break along the west and north-west frontiers of India, recommended in 1954, to consist of a belt of trees 400 miles (656 km) long and 5 miles (8.2 km) wide are discussed by Singh (1957). Trees 60 ft. (18 m) high would give protection from the westerly winds for a distance of only 1,200 ft. (360 m). Similar recommendation of shelter belts to check erosion is given by Prakash (1959). Some afforestation problems and research needs in relation to erosion control in arid and semi-arid areas are discussed by Bhimaya and Kaul (1960), and Kaul and Ganguli (1964). Further, an appraisal of technique of plantation of windbreak in the mechanised form has been given by Bhimaya and Choudhary (1961). Raheja (1963) concludes that *Prosopis juliflora, Albizzia lehbek, Tamarix articulata* and *Azadirachta indica* are the suitable species for shelter belts on sand dunes. The tree belt should be 13m wide interspersed with 60m wide grass strips. Raheja (1964) has also given land transformation plan of Central Luni Basin in W. Rajasthan. Bhimaya *et al.* (1963) have given species suitable for afforestation of different arid habitats of Rajasthan; root system of four desert tree species has also been studied (Bhimaya and Kaul, 1965). Kaul *et al.* (1966) emphasize the importance of micro-relief in development of vegetation in arid zone.

Recently, Bhimaya *et al.* (1966) have described the economics and efficiency of different types of fencing for soil conservation in western Rajasthan; Mishra and Prasad (1966) suggested strip cropping for erosion control. Dry zone afforestation symposium and its recommendation are summarised by Waheed Khan (1961).

Non-toxic chemical antitranspirant which may be used in aid to soil moistures conservation is discussed by Lahiri (1966).

XI—CONCLUSIONS AND RECOMMENDATIONS

From the foregoing review it would be clear that the range resources of Rajasthan are poor and much below their carrying capacity. The interplay of anthropogenic pressure and climatic hazards is responsible for it. Hence there is an urgent need to maintain the grasslands under the existing climate by minimising the former. Indeed a four

point programme has been just suggested by Mukhtar Singh (1968) for management of grasslands in Rajasthan. They are :

1. Fencing or exclosing the grasslands from grazing.
2. Weed control to eradicate useless forbs from the fenced grasslands.
3. Light dressing of fertilizer to improve the productivity of grasslands.
4. To introduce superior grasses and suitable legumes by reseeding.

While the writer agrees with these proposals in principle, something remains to be added :

i) As discussed earlier, application of fertilizers in natural, grasslands will not be beneficial in arid zones of India.

ii) Any superior species exotic to arid climate in no way can fare better than the local types, which have been well adapted to the regional conditions.

iii) The unpalatable forbs may not be removed by any practice. For, these would be the plants that will ultimately make the soil and improve water holding capacity.

It is certain that in India status of grasslands is due to anthropogenic pressure, upon removal of woody vegetation. When degraded and overgrazed areas are fenced, secondary succession follows a certain sequence depending on the condition of the site. At every step water holding capacity of soil increases (Pandeya, 1951-52); annuals are replaced by perennials, and then only, woody vegetation shall start coming up. Eradication of unpalatable forbs will create imbalance, because palatable grasses may not dominate in the initial stage. Best would be to keep these fenced areas as hay plots and harvest them every year after monsoon, removing the unpalatable part from the harvest. Within 2-3 years of such practice, the area will have good grass growth.

iv) A full programme should be immediately undertaken to study the potentials of grasslands and woodlands of Rajasthan. Both primary and secondary productivity must be known. This has to be done on international standards, i.e. on oven-dry basis/unit area/unit time, and under no biotic disturbance. Thus the data will be in line with the International Biological Programme. Once productivity potentials are known, efforts can be made to produce that much by mere fencing the area.

Hence, the writer proposes the following steps for grassland management in Rajasthan :

1. Immediate fencing of all available areas.

2. Study of productivity potentials and trends in succession in representative areas.
3. Harvest of hay every post-monsoon and stocking the harvest after removing unpalatable forms.
4. Not permitting animals to graze in any field.
5. Creation of grass banks.
6. Reseeding by indegenous grasses.

XII—SUMMARY

According to the figures compiled by Whyte (1964), total cattle in Rajasthan in 1956 was 12,072,713 and the number was steadily rising. In contrast to this, grassland productivity of Rajasthan is low, and the balance sheet is on negative side. Grasslands come up in the area only during the short monsoon season, and are so maintained due to anthropogenic pressure. Mainly due to arid and semi-arid bioclimate, grasslands in the tract are generally not dense. Most of the grasslands are overgrazed and lose their green foliage by the month of October. Extensive trials are being made to grow forage plants.

The dominant natural grasses are perennials, which remain leafless for greater part of an year, e.g., *Dichanthium annulatum*, *Cenchrus ciliaris*, *C. setigerus*, *Cynodon dactylon*, *Elionurus hirsutus*, *Heteropogon contortus*, etc. Annuals include *Cenchrus biflorus*, several species of *Eragrostis*, *Dactyloctenium aegyptium*, species of *Aristida*, *Sporobolus*, *Chloris* and *Eleusine*, etc.

The review describes the range resources of Rajasthan under the following heads :

1. The grass cover
2. Important grasses and their drought resistence
3. Forage production, nutritive status and seed output of some promising grasses and legumes
4. Ecology of grassland and grass species
5. Grassland climatology
6. Improvement of grassland and other fodder crops

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S C. Pandeya : They behave true. There is no difference in the 3 generations we have studied.

A.K. Chakravarty : The author used the term 'genotype' in classifying the different ecotypes of *Cenchrus ciliaris* without having made any breeding on this species. Will he please justify the use of the term in the context of mendelian hypothesis ?

S C. Pandeya : 'Genotype' is a perfect word to be used more so when *Cenchrus ciliaris* is established as obligate apomictic form. Hence there is no question of cross breeding. Refer Turesson (1927).

M.N. Tiwari : *Have you not studied chromosome morphology* at *meiosis ?*

S.C. Pandeya : Yes, meiosis application stage was analysed.

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Discussion

M.N. Tewari : How do you rule out the possibility of fertilization without dealing with the local agro climatic condition ?

S C. Pandeya : In general in Rajasthan the limiting factor is water and not minerals. Fertilization on ad-hoc basis will decrease growth.

Chairman : When we discuss some thing about whole of Rajasthan, we have to consider the agro-climatic conditions and differential fertilization of the soils. Rajasthan not only includes arid and semi-arid tracts but also the areas of rainfall with 40" or so. Need of the nitrogen fertilization is important in some tract. I emphasise nitrogen which is not a mineral

R K. Gupta : It was pointed out that the productivity studies on sown and natural pastures have been taken up by the Ecology Section. The main difference between the productivity studies carried out at CAZRI and suggested under IBP is that productivity studies are on oven dry matter/unit area and take into consideration Energy flow and mineral cyclins

S C Pandeya : Yes

A.K. Chakravarty : As the vegetation complex of the range lands in Rajasthan consists of different perennial and annual grasses, do you have any suggestion to measure the rhythm of growth of this complex vegetation ?

S C. Pandeya : Yes, two types of studies are required, viz. productivity per unit area and productivity per species per unit acre (with its density known).

R.N Kaul: In the Central Arid Zone Research Institute studies on rangelands do take into account the productivity, viz. forage production per unit area per unit time and also the animal production in relation to carrying capacity. I would, therefore, like to know the difference in the concept of productivity as envisaged under IBP compared to the studies made or in progress at the Institute.

S C. Pandeya : In IBP studies, productivity rates, standing biomass and net productivity are studied seasonally. The two things are different.

S.K. Saxena : As suggested by Dr. Pandeya regarding the productivity of grasslands, I have to inform that study of productivity of natural pastures and sown pastures is in progress at CAZRI, Jodhpur.

S.C. Pandeya : It is an excellent work and we await your results

S K. Jain : How does the seed or clone behave if it has been raised in a neutral garden for 3 or 4 generations ?

Table 1 Contd.

Locality	Soil Type	Grazing Intensity	Grassland Type	Author and Year	Remarks
	dunes formed by deep-fine sands of aeolin origin				
	5. Saline alluvium with medium heavy calcareous sands and saline soils	Frequent grazing	5. Succulent halophytic desert		
Central Luni basin (W. Rajasthan)	Alluvial plains	Highly degraded grasslands due to heavy grazing	Five grassland types distinguished 1. *Sehima-Dichanthium* type 2 *Cenchrus* type 3. *Eleusine* type 4. *Cynodon* type 5. *Aristida* type	Shankaranarayan and Satyanarayan (1964)	*Sehima - Dichanthium*, and *Cenchrus* types are as excellent, *Eleusine* and *Cynodon* types as fair, and *Aristida* type as poor condition class
Churu (W. Rajasthan)	a) Northern locality	Continuous grazing	a) *Cenchrus - Dactyloctenium-Cyperus*	Sharma (1962, 1965)	
	b) Western locality		b) *C. biflorus-Dactyloctenium-Digitaria-Sanguinalis-Cyperus arenarius*		
	c) Eastern locality		c) *Cenchrus-Cyperus-Leptidenia*		
	d) South-Eastern locality		d) *Digitaria-Dactyloctenium-Cenchrus*		
	e) Southern locality		e) *Tephrosia-Cenchrus-Cyperus*		
Jodhpur	—	Continuous grazing	44 associations recognised in meadows and grasslands	Sen (1966) and Sarup (1952)	

Table 1 Contd.

Locality	Soil Type	Grazing Intensity	Grassland Type	Author and Year	Remarks
Deserts of Rajasthan	—	—	The present position of the plant ecology of the deserts of Rajasthan and Saurashtra	Puri (1952)	—
Desert vegetation	—	—	Desert vegetation	Biswas (1952)	—
Harshnath Hills	—	—	Vegetation of Harshnath Hills	Nair and Nathawat (1957)	—
Indian Desert	—	—	The biological spectrum of the Indian Desert	Das and Sarup (1951)	—
Jaipur Division	—	—	A comparative study of the vegetation of some areas of Jaipur Division	Joshi (1957)	—
Khetri and neighbourhood	—	—	The vegetation of Khetri town and its neighbourhood	Nair, Kanodia and Thomas (1961)	—
Lohargal	—	—	The vegetation of Lohargal	Ratnam (1951), Nair and Malhotra (1962)	—
Mount Abu	—	—	On some ecological features of the vegetation of Mt. Abu	Mahabale and Kharadi (1916)	—

GRASSES AND GRASSLANDS : THEIR DISTRIBUTION AND UTILIZATION IN RAJASTHAN

By

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(With 2 Tables)

I—Introduction

On account of wide variety, pattern of distribution and multifarious uses of the grasses an attempt has been made in the present paper to describe their distribution in major climatic tracts of the Rajasthan State. The grassland types of different land-forms constituting each of these climatic tracts have also been described.

1. *Region*

Rajasthan is an irregular rhombus with east-west and north-south lines as diagonals. It lies between 25°5′ and 30°12′ north latitude and 69°30′ and 78°17′ east longitude covering an area of 3,48,861 square kilometres. The north western part of the State forms the eastern extremity of the north tropical desert belt which extends from the Atlantic coast of Africa through Sahara, part of Arabia, South Persia to Baluchistan. If we move from north-west to north-east the land and climate improve from arid sandy desert to fertile semi-arid and sub-humid tracts. The Mt. Abu region represents the humid climate tract.

2. *Relief*

There is a wide variation in relief in the State. From area with less than 30 m above M.S.L. relief in the vicinity of Rann of Kutch in the west, it gradually increases towards the east with the highest point (1,694 m above M.S.L.) at Mt. Abu. Topography in the western Rajasthan ranges between 30 to 350 m above M.S.L. In general these are plains with a cover of sand interspersed by sand dunes, plateau,

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the forage produced consists of inferior grass species like *Aristida* and a few edible legumes. In addition, a large number of non-edible weeds, viz., *Crotalaria burhia, Teprosia purpurea, Aerva pseudo-tomentosa*, etc., also come up and compete with the grass species for moisture and nutrients. In addition to protection, weed control and reseeding with palatable, nutritious and high forage yielding perennial grass species are, therefore, important for increasing the productivity of the rangelands. Studies on reseeding have revealed that reseeding alone increased forage production by 60 per cent and the cost-benefit ratio of the reseeded pastures worked out to 1.

Grazing management according to the carrying capacity of the rangelands is also important to maintain their productivity. Grazing studies with heifers conducted in the rocky range of low productivity at Kailana (near Jodhpur) revealed that light intensity grazing (6 ha per cattle) allowed 60 per cent utilization of the vegetation consistent with animal growth and range conservation. Further studies have shown that poor condition natural rangelands at Pali could sustain one sheep per 2.5 ha, whereas sown pastures of *Cenchrus ciliaris* could support 7.6 sheep per ha. without impairing the rangelands.

of the vegetation type, however, is influenced to different degrees by biotic disturbances. This can be observed in various progressive and retrogressive stages in the State depending upon the degree of abuse. Dabadghao (1960) has suggested one grassland type, viz. *Dichanthium - Cenchrus - Elyonurus* type for the entire State. He has not taken into consideration the ecological amplitude of the key species which are directly influenced by climatic regions, landscape and other edaphic factors. Raheja and Sen (1964) have based their 12 grassland types only on micro-climatic tracts. They have not recognised the effect of landscape and edaphic factors which have a direct bearing on the distribution of grassland types. Shankarnarayan and Satyanarayan (1964) have described five grassland types for alluvial flats. Prakash and Nanda (1961) have described the progressive and retrogressive grassland land communities on three eco-systems and one sub-ecosystem of western Rajasthan. In the current investigation the effect of climate, physiographic features, soil and other edaphic characteristic on the protected grassland reserves has been studied. Based on these studies twenty-two grassland types have been established for the entire State. The major grassland types and the associated tree species with respect to habitat and climatic tracts are shown in Table 1.

II—MATERIAL AND METHOD

The study of the differences in the structure of the grassland types occupying varied habitats in the different climatic regions has been made in two different ways.

i) Listing and classification of the different grass species as they occur in each climatic region.

ii) The sociological interrelationship of the grass species on specific habitat within each micro-climatic region has been studied by the modified adaptation of step point method of Costallo and Schwan (1946) and the loop method of Parker (1954).

The forage production has been estimated by cutting randomly laid ten 3m × 3m quadrats and air drying the grass for 15 days. After cutting the grass ocular estimation of total ground cover was also noted. The soil analysis has been done by rapid testing methods as described by Piper (1950). The soil characteristics of each grassland type are presented in Table 2.

bosses of granite rhyolite and many depressions where the streams are internal and misfits. On the eastern fringe the desert is scraped by typical Aravalli landscape of parallely arranged hills rising to a height of 1500 m above M.S.L. at Mount Abu. The Aravallis also stretch towards Udaipur where they attain a height of 1050-1200 m above M.S.L. The districts of Kota, Bundi, Chittorgarh and Bhilwara constitute the plateau region. The rest of the area extending east of Aravallis in the districts of Jaipur, Alwar, Bharatpur, Ajmer, Sawai Madhopur and Tonk is largely an alluvial plain.

3. *Environment*

The climate in major part of the State is characterised by low and erratic annual rainfall, high potential evaporation and great extremes of temperature. The diurnal variation of temperature is generally sudden and great. The entire State, except at Mount Abu, is exposed to strong winds. The climate is strongly monsoonal with rainy season from July to October. The State can be divided into five climatic tracts based on the Thornthwaite (1948) empirical formula.

4. *Soils*

Very little scientific information is available on the composition and characteristics of grassland soils of Rajasthan. The soils of Rajasthan State have been grouped into thirteen soil associations by Roy and Sen (1968). They have discussed the properties of each type in detail. However, some of the soil properties of the main grassland types have been described in Table 2 for ready reference.

5. *Land-Forms*

For detailed study and fixing grassland types, each climatic region has been divided into specific land-forms based on edaphic and physiographic factors.

6. *Vegetation*

The vegetation of the Rajasthan State has five major divisions based on the climatic tracts. The distribution of dominant tree and grass species forming vegetational types is controlled by the physiographic features, soil characteristics and other edaphic features. Each

in the semi-arid zone. Further eastwards in the sub-humid zone this land-form supports *Dichanthium annulatum* and *Eremopogon foveolatus* type. However, in the humid zone at Mount Abu *Dichanthium annulatum* is replaced by *Bothriochloa pertusa* and it forms a characteristic community with *Arundinella pumila* and *Arthraxon* spp.

The saline depressions, where the grasses are subjected to both physical and physiological drought, support *Sporobolus marginatus-Desmostachya bipinnata* type in extremely arid tracts. In semi-arid tract this type changes to *Sporobolus marginatus, S. helvolus, S. coromandelianus* and *Echinochloa colonum* type. Associated with this type *Iseilema prostratum* forms distinct colonies in depressions where moisture remains accumulate and *Sehima ischaemoides* forms colonies on well drained shallow soils. In the sub-humid tract, however, the main type remains the same but *Iseilema prostratum* is replaced by *I. laxum* and *Paspalidium flavidum*. *Sehima ischaemoides* gets eliminated from the community. However, *Ischaemum* spp. are observed in small patches.

Most of the seasonal streams in the extremely arid tract drain in saline depressions (Ranns) and hence the grassland type virtually is similar to that of saline depressions. In the transitional and semi-arid tract the riverian land-form is occupied by *Saccharum spontaneum*. *Vetiveria zizanioides* and *Halopyrum mcuronatum* type. This type is replaced by *Saccharum spontaneum-Desmostachya bipinnata* type where the streams pass through sandy terrain and *Saccharum spontaneum—Vetiveria zizanioides* type where streams pass through sandy clay loams. Similarly *Saccharum spontaneum* is replaced by *Halopyrum mucronatum* where streams pass through saline soils. A single exception to the above type has been observed on both sides of Banganga near Bilara where *Phragmites karka* and *Arundo donax* from a community.

In the sub-humid tract this land-form is occupied by *Saccharum spontaneum, S. bengalensis, Phragmites karka* type. Similarly it is replaced by *Saccharum spontaneum, Pseudopogonatharum contortum* type in the humid tract at Mount Abu.

Sand dunes which occupy a sizable area only in the extremely arid tract are occupied by *Panicum turgidum* and *Panicum antidotale* type.

From the above observations it may be seen that each climatic tract shows distinct and different grassland types on similar habitats. The climate also influences the soil properties (Table 2). Like grassland type the forest vegetation types are also influenced by the climate.

III—Discussion

It is interesting to note that each climatic tract shows distinct and different grassland types on apparently similar habitats (Table 1). Minor variations in soil properties are also noted (Table 2). The rock and gravel formations which are distributed all over the State show that grassland types under each climatic region are characteristic. The limit of distribution of major forage yielding grasses, from these formations, like *Themeda triandra*, *Apluda mutica*, *Sehima nervosum*, *Chrysopogon fulvus*, *Eremopogon foveolatus*, *Cymbopogon* spp. is clearly demarcated. The colonies of *Themeda triandra* and *Apluda mutica* do not extend beyond humid and sub-humid terrain. However, stray plants of *Apluda mutica* are met with in all the climatic regions. *Chrysopogon fulvus* is restricted to semi-arid and sub-humid tracts. *Sehima nervosum* does not form sizable communities beyond semi-arid tract although some plants have been collected from the transitional arid tract near Jodhpur.

The old alluviums also show characteristic grassland types in different climatic tracts of the State. The distribution of *Lasiurus sindicus* and *L. ecandatus*, the most important desert fodder grasses, is restricted only to the old alluviums with aeoline deposits, interdunal areas and from the foot to the middle of stabilised dunes in extremely arid tract. The old alluviums without aeoline deposits in this terrain are occupied by *Eleusine compressa*, *Dactyloctenium sindicus* and *Aristida* spp. This type is modified to *Cenchrus* spp.—*Eleusine compressa-Aristida* spp. type in the transitional arid tract, and *Cenchrus* spp.—*Aristida* spp. type in the semi-arid tract. This shows that as the climate improves *Eleusine compressa* gets suppressed by other better adapted forage species. In the sub-humid zone and plateau region the grassland type is markedly different consisting of *Iseilema laxum*, *Dichanthium annulatum*, *D. aristatum*, *Echinochloa colonum*, etc. (Table 2). Similarly in the humid region at Mount Abu this land-form is occupied by *Pennisetum hohenackeri*, *Cynodon dactylon*, *Arthraxon* spp., etc. With the change in the grass cover in sub-humid and humid tracts a marked change in the soil texture and properties is also observed (Table 2).

The young alluviums with annual moisture and silt deposition are occupied by *Dichanthium annulatum-Cenchrus* spp. type in extremely arid to arid tracts. This type is replaced by *Dichanthium annulatum* and *Demostachya bipinnata* type with *Cenchrus* spp. only on well drained soils

The humid tract showed the presence of 89 grasses out of the 135 species identified as a result of intensive collection and survey of grasslands in the State. Of these only 26 grasses participate in forming four distinct grassland types depending upon the habitat soil characteristics. From these twenty-six grasses, however, *Themeda traindra*, *Heteropogon contortus*, *Apluda mutica* from the gravel and rock formation provide good hay whereas *Cymbopogon martinii* provides thatching material. *Bothriochloa intermedia* and *B. pertusa* are the only perennial forage grasses from the undulating terrain whereas *Arundinella punula* and *Arthraxon* spp. are short lived annuals or biennials. Similarly *Pennisetum hohenackeri* provides hay and *Cynodon dactylon* short green forage from the flat alluviums which are subjected to seasonal flooding and the borders of perennial streams.

The saline depressions, on which grasses are subjected to both physical and physiological drought in extremely arid, arid and semi-arid tracts, support distinct grassland types, viz. *Sporobolus marginatus - Desmostochya bipinnata* on extremely arid and arid tracts and *Sporobolus* spp.-*Echinochloa colonum* type in semi-arid and sub-humid tracts. From the large number of species recorded from the four climatic tracts only seventeen grasses figure on the saline depressions. *Sprobolus* spp., *Aeluropus lagopoides*, *Chloris* spp., *Eragrosticella bifaria*, *Schoenfeldia gracilis*, *Echinochloa colonum*, *Cynodon* spp. and *Desmostachya bipinnata* are the most salt tolerant species. However, most of the sites under these soils being undulating less salt tolerant species like *Eremopogon foveolatus*, *Eleusine compressa*, *Dactyloctenium sindicum*, *Dichanthium annulatum*, *Aristida fnniculata*, occupy the better drained and leached hummocks. Since most of the area under these soils is subject to grazing by all kinds of animals, the population of grasses is very sparse and patchy. But when the area is protected from grazing the salt tolerant grasses take over the area gradually and make it suitable for supporting better and succulent forage species like *Dichanthium annulatum* and *Eremopogon foveolatus* in flat alluviums, and *Cenchrus setigerus*, *Cenchrus ciliaris*, *Eleusine compressa*, *Dactyloctenium sindicum* grow in better drained sandy soils. It has been observed that deep ploughing or contour furrowing 25 cms deep and 3-5 meters apart help in quicker rehabilitation of these unproductive soils with the productive perennial forage grasses. Other salt resistant unpalatable weeds also contribute to the reclamation of such a soil.

and edaphic and soil characteristics (Table 1).

Of the large number of grasses present in each climatic region only a few actually participate in making up different grassland types. Of these still fewer are useful for forage production and soil conservation.

In the extremely arid climatic tract sixty-one species have been recorded. From these only twenty species participate in the first five grassland types. Amongst these, *Lasiurus sindicus*, *Eleusine compresssa*, *Dactyloctenium sindicum*, *Dichanthium annulatum*, *Cenchrus ciliaris* and *Panicum antidotale* are the only important natural forage grasses. The other three species which occupy dominant position in the grassland types, viz. *Cymbopogon parkeri*, *C. jwarancusa* and *Panicum turgidum* are useful for soil conservation; they are not palatable to the animals.

The arid or transitional climatic tract supports 87 grasses; of these only 23 grasses participate in the three grassland types excluding that found on saline habitats which are discussed separately. *Cenchrus* spp., *Eleusine compressa*, *Dactyloctenium sindicum* and *Aristida* spp. only make significant contribution to forage production. Attempts at introducing *Lasiurus sindicus* on old alluvial flats at Central Research Farm, Jodhpur, have met with a grand success. The presence of *Sehima nervosum* at Kailana rocks is an interesting feature as beyond Jodhpur this species has not been observed.

From the 122 grass species only 23 have been observed to participate in the respective grassland types of semi-arid tracts. Amongst these *Heteropogon contortus*, *Chrysopogon fulvus*, *Sehima nervosum*, *Bothriochloa pertusa* from the rock and gravel formations, *Cenchrus setigerus*, *C. pennisetiformis* and *Aristida* spp. from the old alluviums, *Dichanthium annulatum*, *Eremopogon foveolatus* from well drained young alluviums are the important perennial forage species.

The sub-humid tract supports 134 grass species. The four grassland types studied show that only 28 grasses participate in the botanical composition (Table 2). From these *Eremopogon foveolatus*, *Dichanthium annulatum*, *Heteropogon contortus* on the rock and gravel formations, *Iseilema laxum*, *Echinochloa colonum*, *Dichanthium aristatum* on alluviums and *Eragrostis tonella*, *Ischaemum rugosum* on the riverian soils are important fodder species that need rehabilitation for enabling the grasslands under each land-forms to give optimum production.

Discussion

S.C. Pandeya : You have mentioned that it is not possible to determine new dry weight of harvests I may suggest that you may take fresh weights in fields and despatch samples to laboratory in polythene or Calico bags for oven drying at 80°C This will standardise your results and make it comparable with those of others and IBP Air dry weights are not comparable.

P C. Nanda : It was pointed out that it was not possible while conducting work in sporadic attempts, however, the suggestion is welcome.

S K. Jain : (1) Whether *Dichanthium aristatum* is different from other species is doubtful, (2) It is wrong to include *Salsola/Sueda* as forest types. Better mention only the tree or high shrub spp., (3) Identification of *Arthraxon lanceolatus* should be checked

P.C. Nanda : (1) *D aristatum* is retained on the basis of Bor's work. In fact detailed eco-typic work of *Dichanthium* complex in Arid Zone is under progress and results so far obtained warrant us to retain it, (2) Since except *Tamarix* spp. no other shrub or small tree occurs on these soils, the woody plants have been included to indicate the associated other woody species, (3) It is a good suggestion, it would be kept in view.

M Hasan : What is the correlation between the distribution of different types of grasslands and the density of animal distribution in Rajasthan ?

P C Nanda : It is an interesting point, which needs attention. It is, however, beyond the perview of this paper.

Geo R. Gist : Do you find the same grassland communities under controlled grazing as under ungrazed plots ?

P.C. Nanda : Yes, in fact judicious controlled grazing helps in maintaining the stable grassland type. Attention is drawn to recent work by Kaul et Nanda (1967), Annals of Arid Zone, where beneficial effect of controlled grazing has been shown in *Cenchrus-Aristida* grassland type.

Mukhtar Singh : The effect of land forms has been discussed on the distribution of grasses in Rajasthan—What do you think is the effect of aspect factor, with reference to vegetation on sand dunes.

P.C. Nanda : Aspect has a direct bearing on the density of the vegetation but the component species remain the same.

J K. Maheshwari : It would be worthwhile to classify the grassland types into major subtypes on the basis of climatic, edaphic and biotic factor.

P.C. Nanda : It is a good suggestion, in fact work is under progress in this direction.

R.K Gupta : In the abstract twenty two grassland types have been given while in *presenting the paper twenty two communities have been mentioned.* Could you explain this anamoly ?

P C. Nanda : The word community was used only to describe the retrogressive stages of the main type. The types discussed are based on 10 to 12 year closure and proper management of the grasslands.

IV—CONCLUSIONS

From the above discussion it is apparent that each climatic tract shows distinct and different grassland types on apparently similar habitats (Table 1). The limit of distribution of the major forage yielding grasses is clearly demarcated and is based on climate and edaphic features in the State. In order to enable each land-form to provide optimum forage production based on land capability, efforts have to be directed towards the establishment, development and multiplication of specific grasses through controlled grazing, proper soil working and reseeding.

V—SUMMARY

Twenty-two grassland types have been recognised from the five major climatic regions of Rajasthan. The importance of each grassland type with respect to forage production, soil conservation and soil improvement has been discussed.

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Table 1 Concluded

Climatic tract	Land-form	Grassland types	Associated forest types
	Young alluviums	12. *Dichanthium annulatum—Eremopogon foveolatus*	*Prosopis cineraria—Salvadora oleoides*
	Saline depressions	13. *Sporobolus marginatus—Echinocholoa colonum*	*Acacia jacquemontii—Salvadora* spp., *Salsola barymbosa, Suaeda fruticosa*
	Riverian	14. *Saccharum spontaneum—Vetiveria zizanoides-Halopyrum mucronatum*	*Acacia jacquemontii—Tamarix dioica*
Sub-Humid (CW)	Rocks & Gravel formations 0 15% slope	15. *Eremopogon foveolatus—Dichanthium annulatum-Heteropogon contortus*	*Butea monosperma— Wrightia tinctoria Zizyphus nummularia—Mimosa hamata*
	Alluvial flats with undulating topography	16. *Iseilema laxum—Dichanthium annulatum Echinochloa colonum*	*Acacia nilotica—Acacia catechu*
	Saline depressions	17. *Sporobolus marginatus—S helvolus—Echinochloa colonum*	*Butea monosperma*
	Stream banks	18. *Saccharum spontaneum—Phragmitis karka* type	—
Humid (Mount Abu)	Rocks & Gravel formation 8-15% slope	19. *Themeda triandra- Cymbopogon martinii*	*Anogeissus latifolia, A. sericea, A. pendula, Euphorbia caducifolia*
	Undulating foot hills (alluviums) 0-7% slope	20. *Bothriochloa* spp. —*Arthraxon* spp *Arundinella pumila*	*Pheonix sylvestris—Syzyium cumini—Mangifera indica—Carissa* spp
	Alluvial flats with seasonal flooding	21. *Pennisetum hohenackeri—Cynodon dactylon*	—do—
	Stream banks	22. *Saccharum spontaneum—Pseudopogonatherum contortum*	—

Table 1. Grassland Types of Rajasthan

Climatic tract	Land-form	Grassland types	Associated forest types
Extremely arid	Rock & Gravel formations	1. *Cymbopogon* spp —*Eleusine compressa*—*Aristida* spp.	*Acacia senegal*—*Euphorbia caducifolia*, *Commiphora mukul*
	Rock folds and Khadins (Young alluviums)	2. *Dichanthium annulatum*—*Cenchrus* spp.	*Prosopis cineraria*—*Acacia nilotica*
	Sand dunes	3. *Panicum turgidum*—*Panicum antidotale*	*Calligonum polygonoides*
	Interdunal areas and old alluviums with aeoline deposits	4. *Lasiurus sindicus*—*Eleusine compressa*	*Prosopis cineraria*—*Haloxylon* spp. *P. cineraria*—*Acacia jacquemontii* *P. cineraria*—*Zizyphus nummularia* *P. cineraria*—*Calotropis procera*
	Old alluviums	5 *Eleusine compressa*—*Dactyloctenium sindicum*—*Aristida* spp.	*P. cineraria*—*Salvadora* spp.
	Saline depressions	6 *Sporobolus marginatus*—*Desmostachya bipinnata.*	*Tamarix* spp. *Sueada fruticosa*—*Salsola barymbosa*
Arid or Transitional zone	Rocks and Gravel formations	7. *Eleusine compressa*—*Dactyloctenium sindicum*—*Oropetium thomaeum.*	*Acacia senegal*—*Grewia populifolia*
	Old alluviums	8. *Cenchrus* spp.—*Eleusine compressa*—*Aristida* spp.	(a) *Prosopis cineraria*—*Capparis decidua* (b) *Prosopis cineraria*—*Salvadora oleoides*
Semi-Arid	Rocks & Gravel formations	9. *Heteropogon contortus*—*Chrysopogon fulvus*—*Bothriochloa pertusa*	(a) *Anogeissus pendula* (b) *Acacia leucophloea*, *Dichrostachya cineria* etc.
	Rocks & Gravel formation (Undulating terrain 0 15% slope)	10. *Sehima nervosum*—*Heteropogon contortus*	*Acacia senegal*, *Capparis decidua*, *Zizyphus nummularia*
	Old alluviums	11. *Cenchrus* spp , *Aristida* spp.	*Anogeissus pendula* – *Prospopis cineraria* *Balanites roxburghii*

Table 2 Contd.

GRASSLAND TYPE	SOIL CHARACTERISTICS Colour	pH	Total soluble Salt	Water holding capacity	Gravel per-cent	Sand per-cent	Silt per-cent	Clay per-cent	TEXTURE	PLACE
10. *Sehima nervosum - Heteropogon contortus*	Light olive brown	7.5	0.021	30.2	3.1	70.03	9.0	20.0	Sandy loam to sandy clay	Forest enclosure, Sirohi
11. *Cenchrus* spp.-*Aristida* spp.	Light grey brown	7.95	0.014	23.0	7.5	85.8	6.08	8.1	Loamy sand	RM & SC area, Sojat City, Dist. Pali
12. *Dichanthium annulatum-Eremopogon foveolatus*	Olive grey	7.9	0.021	45.7	6.5	55.0	12.25	33.75	Sandy clay loam	RM & SC Area, Bisalpur, Dist. Pali
13. *Sporobolus marginatus-Echinochloa colonum*	Light grey brown	8.5	0.021	16.70	4.2	90.3	4.5	5.2	Sandy	RM & SC Area, Bilara, Dist. Jodhpur
14. *Saccharum spontaneum-Vetiveria zizanioides-Halopyrum mucronatum*	—	—	—	—	—	—	—	—	—	Dist. Pali & Ajmer
15. *Eremopogon foveolatus-Dichanthium annulatum-Heteropogon contortus*	Light olive	7.1	0.021	35.5	6.0	44.20	21.30	33.7	Clay loam	Siyava Hill, Abu Road, Dist. Sirohi
16. *Iseilema laxum-Dichanthium annulatum-Ecinochloa colonum*	Light olive grey	6.5	0.007	34.75	4.0	81.0	9.5	6.5	Loamy sand	Jhalawar Grass Bir
17. *Sporobolus marginatus-S.helvolus-Echinochloa colonum*	Similar as type (13)	—	—	—	—	—	—	—	—	Jhalawar Grazing Area
18. *Saccharum spontaneum-Phragmites karka*	—	—	—	—	—	—	—	—	—	Near Abu Road

Table 2. Soil Characteristics of the Grassland Types

GRASSLAND TYPE	SOIL CHARACTERISTICS								TEXTURE	PLACE
	Colour	pH	Total soluble Salt	Water holding capacity	Gravel per-cent	Sand per-cent	Silt per-cent	Clay per-cent		
1. *Cymbopogon* spp. - *Eleusine compressa-Aristida* spp.	Light yellow brown	8.0	0.007	26	4.5	92.5	4.5	4.1	Shallow sandy soils	RM & SC Area, Jaisalmer
2. *Dichanthium annulatum-Cenchrus* spp.	Light yellow brown	7.6	0.001	28	2.3	86.6	8.2	5.2	Loamy sandy	Shiv-Gadra Road, Barmer
3. *Panicum turgidum - Panicum antidotale*	Light yellow brown	7.8	0.007	27	1	89.1	5.4	5.2	Sandy	Nachna, Dist. Jaisalmer
4. *Lasiurus sindicus - Eleusine compressa*	Light yellow brown	8.0	0.021	24	1	4.5	90.3	5.2	Sandy	Chandan, Dist Jaisalmer
5. *Eleusine compressa-Dactyloctenium sindicum - Aristida* spp.	Very pale brown	8.1	0.014	23.91	3.5	91.1	4.0	4.9	Sandy	Dhulia, Dist. Jaisalmer
6 *Sporobolus marginatus-Desmostachya bipinnata*	Light grey brown	8.5	0.028	22.22	9.3	88.8	5.0	6.2	Sandy (Upper layer 0.5 cm sticky)	Neemli, Dist. Jodhpur
7. *Eleusine compressa-Dactyloctenium sindicum-Oropetium thomaeum*	Light yellow brown	8.2	0.021	16.70	3.1	90.3	4.5	5.2	Sandy	Kailana Enclosure, Jodhpur
8. *Cenchrus* spp - *Eleusine compressa-Aristida* spp.	Light yellow brown	7.5	0.001	27.60	2.3	86.6	8.2	5.2	Loamy sand	C.R. Farm, CAZRI, Jodhpur
9. *Heteropogon contortus-Chrysopogon fulvus-Bothriochloa pertusa*	Light brown grey	6.5	0.001	19.95	12.2	86.5	7.0	6.5	Loamy sand	Bhanwar Jikabir Chittorgarh

FOREST RESOURCES OF RAJASTHAN

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I—Introduction

1. General

The State of Rajasthan lying between the geographical location of 23° 30′ and 30° 12′ North latitudes and 69° 30′ and 78° 17′ East longitudes occupies an area of 3,42,274 sq. km. The forest area comprises nearly 37,638 sq. km, i.e., about 11% of the land area, with a low *per capita* area of 0.17 ha. Within the forest area, about 7% is denuded and depleted forest owing to past maltreatment and the remaining is comparatively better stocked.

The physical features of Rajasthan are characterised chiefly by the Aravali Ranges which run north-east to south-west, dividing the State into two zones, viz., the sandy, unproductive, north-west and the comparatively fertile south-east. The Aravalis form the main dividing line between the major watersheds also, and are composed of phyllites and intercalated quartzites. Granites are characteristic of the Abu hills. The interesting geological features include Vindhyan rocks of late pre-Cambrian to early-Cambrian age in eastern Rajasthan, sand-stones of Damuda age in Jaisalmer and upper Gondwana age in south-east of Jaisalmer, lime-stones and shales of uppermost Jurassic age in Jaisalmer and Bikaner, Balmir sand-stones of Cretaceous age in Barmer and geological formations of Eocene age in Jaisalmer and Bikaner.

The drainage of the land is largely internal with about 60% of the land area under inland drainage, the main river catchments being Chambal catchment (20.9%), Luni catchment (10.3%), Mahi catchment (4.6%), Jamuna-Ganges catchment (1.5%) and Sabarmati catchment (1.0%).

Table 2 Concluded

GRASSLAND TYPE	SOIL CHARACTERISTICS								TEXTURE	PLACE
	Colour	pH	Total soluble Salt	Water holding capacity	Gravel per-cent	Sand per-cent	Silt per-cent	Clay per-cent		
19. *Themeda triandra-Cymbopogon martinii*	Light olive brown	6.1	0.028	37.2	24 5	59 50	17 5	22 50	Sandy clay loam	Bimalia, Mt Abu
20. *Bothriochloa* spp.-*Arthraxon* spp	Pale olive	6 0	0 021	26 3	17 1	72 35	17.50	10 15	Sandy loam	Ahobi Ghat area Mt. Abu
21. *Pennisetum hohenackeri-Cynodon dactylon*	Pale olive	6 9	0 028	47 8	5 4	62.50	16 25	21.25	Sandy clay loam	Oria Grass Bir Mt. Abu
22. *Saccharum spontaneum-Pseudopogonatherum contortum*	—	—	—	—	—	—	—	—	—	Dhobi Ghat Area Mt. Abu

edaphic climax of tropical dry deciduous forests—5/E1, (ii) *Acacia catechu* forests corresponding to Champion's edaphic climax of tropical dry deciduous forests—5/E2, (iii) *Boswellia serrata* forests corresponding to Champion's edaphic climax of tropical dry deciduous forests—5/E5, (iv) *Butea monosperma* forests corresponding to Champion's edaphic climax of tropical dry deciduous forests—5/E9, (v) *Dendrocalamus strictus* forests corresponding to Champion's edaphic climax of tropical dry deciduous forests—5·E9 (dry bamboo brakes), (vi) *Tectona grandis* forests corresponding to Champion's edaphic climax of tropical dry deciduous forests—5A/C1a (very dry teak forests), (vii) *Mixed Miscellaneous* forests corresponding to Champion's northern dry mixed deciduous—5B/C2, (viii) *Subtropical evergreen* forests corresponding to Champion's central Indian sub-tropical hill forest—8AC3 and (ix) *Thorn forests* corresponding to Champion's desert thorn forests—6B/C1.

(i) *Anogeissus pendula* (dhauk) forests : This is the principal type of forest covering about 60% of the forest area (10,200 sq miles). The dominant species is *Anogeissus pendula* which often forms pure stands. *Acacia catechu, Butea monosperma, Bauhinia racemosa, Wrightia tomentosa, Acacia leucophloea, Lannea coromandelica* and *Diospyros melanoxylon* form the common associates. The undergrowth consists chiefly of *Grewia flavescens, Nyctanthes arbortristis, Zizyphus nummalaria* and *Balanites aegyptica.* The average height of the crop is about 8 m and the crop density varies from 0.6 to 0.8. These forests are important from the protective point of view as these provide a useful vegetative cover on the water-sheds. *Anogeissus pendula* is also used for small timber, fuel and charcoal.

(ii) *Acacia catechu* forests : This species which is economically important for the production of *katha*, occurs almost pure in patches and sometimes mixed with other species and occupies about 3% of the forest area. It is commonly found in the south-eastern region of the State. The species occurring in association with Khair are *Zizyphus xylopyra, Z. glaberrima, Anogeissus pendula, Dichrostachys marmelos* and *Acacia leucophloea.*

(iii) *Boswellia serrata* forests : *Boswellia serrata* is found in the upper ridges of Aravali hills in shallow soils and covers about *1000* sq miles, forming 5% of the total area. The trees commonly attain a height of 12-13 meters and a girth of 20-25 cm. *Boswellia serrata* is a good packing case timber for which there is increasing demand. Transport costs

2. *Climate*

The climate is hot and arid. The rain fall varies from less than 130 mm to more than 1000 mm (average rainfall 525 mm), and three distinct zones of rainfall distribution can be recognised. These are : (i) the dry subhumid zone of 500-800 mm in the east of Aravalis, (ii) the seme-arid zone of 300-500 mm from the foot-hills of Aravalis in the east to desert plains in the west, and (iii) arid zone of 100-300 mm The bulk of rainfall is received during June to September.

The summer temperatures range from 46.2 to 47.8°C and the highest temperatures are recorded during May. The summers are hot and dry, while cold waves also occur during winter in the north-western part of the arid zone. The minimum temperatures in winter go down to -1.1°C Frost is also a common feature.

3. *Soils*

The soils have developed under arid conditions and have been broadly divided into : (i) desert soils, (ii) grey brown soils, (iii) grey and brown soils of Indogangetic plain, (iv) red and yellow soils, (v) undifferentiated alluvial soils, (vi) black soils, and (vii) eroded and skeletal soils on hill slopes.

In general, most of the soils are poor in nitrogen and organic matter content, deficient in moisture supply and low in fertility level. The soils are alkaline in reaction and contain high concentration of total and exchangeable calcium. The availability of other nutrients like phosphorous and potassium is much less, specially in desert soils, ravines and alkaline soils. In view of the unfavourable conditions, the management of the soils calls for increasing their fertility status, protection of the soils from erosion, moisture conservation and reduction in the salinity and alkalinity. In this respect, the afforestation can play a significant role in overall improvement of the soils.

II—FOREST TYPES

The forest vegetation varies with the climate and soil variations and is also to a great extent modified by biotic influences. Broadly speaking, nine forest sub-types have been recognised in the State, viz. (i) *Anogeissus pendula* forests corresponding to Champion's

The teak forests are potentially valuable forests but having been degraded by indiscriminate hacking, are now being rehabilitated by tending and artificial regeneration. Recent trials with coppicing the malformed growth have shown very good prospects of converting this inferior crop into well-grown stands.

(vii) *Mixed miscellaneous forests* : In the south-eastern region which receives more rainfall, mixed miscellaneous types of forests occur forming about 20% of the total forest area. The dominant species of this type is *Anogeissus latifolia*, associated with *Diospyros melanoxylon, Aegle marmelos, Madhuca indica, Buchanania lanzan, Albizzia odoritissima, Dalbergia latifolia, Schrebra swietinioides, Mitragyna parvifolia, Terminalia belerica, Cassia fistula, Pterocarpus marsupium, Holoptelia integrifolia, Butea monosperma, Mallotus phillipensis*, etc. The undergrowth consists mainly of *Holarrhena antidysenterica, Grewia flavescens, Helictres isora, Zizyphus* spp., etc. The grass cover is luxuriant.

(viii) *Sub-tropical evergreen forests* : The sub-tropical evergreen forests occur over limited extent in about 20 sq miles round Mt. Abu at elevation of 1000 to 1300 m where the rainfall is 1500 mm or more annually. The main species are *Flacourtia indica, Bauhinia purpurea, Erythrina suberosa, Anogeissus sericea, Crataeva religiosa*, etc. *Mangifera indica* and *Syzygium cuminii* occur on the slopes of Mt. Abu. The introduced species are *Pinus roxburghii, Grevillea robusta, Salix* spp. and *Eucalyptus* spp.

(ix) *Thorn forests* : These are found mainly in the arid areas of north-west, ravines and sandy tracts and occupy 1882 ha of area. In the hilly tracts, the species occurring are *Acacia senegal, Grewia tenex, Zizyphus jujuba, Mimosa hameta, Euphorbia caducifolia*, etc., while the unstable sand dunes hardly support any tree growth except some small scrub. The sand dunes are initially colonised by species like *Cyperus arenarinus, Indigofera* spp., *Citrius colocynthis* and annual grass shrubs like *Leptadenia, Crotolaria, Calotropis, Areua javanica, Zizyphus rotundifolia*, etc. come up below. Other species, particularly tree species, come up only when the dunes are stabilised and these consist of *Prosopis cineraria (Prosopis spicegera), Acacia senegul, Salvadora oleoides, Gymnosporia spinosa, Tecomella undulata, Grewia tenex*, etc.

In the pronounced saline areas, such as near Sambhar lake, *Salvadora oleoides* with *S. persica, Tamarix dioca, T. aphylla, Azadirachta*

involved in extracting it from remote areas is a major factor. This species occurs either in pure patches or in mixture. The species occurring as associates are *Sterculia urens* and *Lannea coromandelica*. It is sometimes also mixed with *Emblica officinalis, Anogeissus latifolia* and *Acacia catechu* or with *Zizyphus* spp. In rocky areas there is practically no grass cover but in deeper soils *Apluda, Eragrostis, Themeda quadrivalvis* and *Heteropogon contortus* form the main undergrowth.

(iv) *Butea monosperma* (dhak) forests : This species is characteristic of badly drained clayey soils and occurs chiefly along foothills and depressions. The total area covered is about 565 ha (1.5% of forest area). Dhak usually occurs in pure patches, but where mixed *Dichrostachys cinerea, Acacia leucophloea* and *Zizyphus* form the common associates. The canopy is not more than 8 m high and average crop density 0.6.

(v) *Dendrocalamus strictus* forests : Bamboo covers about 2.5% of the area (940 ha) mostly in parts of Chittorgarh, Udaipur, Kota and Abu hills. It generally forms pure patches in depressions and also in mixture with species like *Anogeissus pendula, Mitragyna parviflora, Cassia fistula, Schrebra swietenoides, Diospyrus melanoxylon, Lannea coromandelica* and *Ougenia oojinensis*. It also occurs in teak forests. The clumps are of varying size with 10 to 30 culms and 5 to 9 m in height. The bamboo forests have, however, deteriorated a great deal due to unsystematic working and congestion in clumps.

(vi) *Tectona grandis* (teak) forests : Teak forests of the dry type occupy over 2635 ha and represent the northern limit of the natural zone of teak in India. Teak occurs commonly in southern and south-eastern parts of the State at elevation of 250 to 650 m in more or less pure stands in Banswara, and elsewhere in mixture with several species. In the northern aspects and better protected areas, the forests are well stocked while in other areas heavy biotic interferences have rendered the teak crop to various stages of degradation. The common associates of teak are *Diospyros melanoxylon, Anogeissus latifolia, Aegle marmelos, Terminalia tomentosa, Dalbergia paniculata, Sterculia urens, Bauhinia racemosa, Soymida febrifuga, Acacia catechu*, etc. On ridges and sloping ground *Boswellia serrata, Cochlospermum gossipyum* and *Wrightia tomentosa* also occur in mixture with the teak crop. The under-growth is sparse and usually consists of *Nyctanthes arbortristis, Helictres isora, Holarrhena antidysenterica*, etc.

dudhi *(Wrightia tomentosa)*, gurjan *(Lannea coromandelica)* are also used in the manufacture of wooden toys mainly in the Sawai-Madhopur and Udaipur regions.

Tendu *(Diospyros melanoxylon)* occurs almost all over the State and large quantities of leaves are extracted for the manufacture of bidis. Bamboo, which is found mainly in Udaipur, Banswara, Chittorgarh, and Alwar, provides mostly domestic requirements and is also used in local cottage industries such as basket making, carpets, curtains and furniture.

2. *Fodder and Grass*

The rural economy of the State is very much dependent on the pastures and grasslands owing to the importance which cattle rearing and animal husbandry occupies in the State. Rajasthan is a major producer of wool and produces nearly 45% of the country's wool production. The cattle population of the State, includes besides miltch cattle, some of the finest breeds of sheep and camels. The total cattle population of the State as per 1963-64 figures was :

Buffaloes	—	43,30,000
Cows & Bullocks	—	1,37,67,000
Sheep	—	87,75,000
Goats	—	77,51,000
Camels	—	6,36,000
Others	—	3,60,000
	Total	3,55,19,000

Though Rajasthan has about 5.3% of the total forest area of India, it has about 10% of the total cattle population. The forests which serve as grazing grounds and largely meet the fodder and grazing requirements of the cattle, play an important role in this respect. The management of grasslands should, therefore, occupy a special position in relation to the rural economy of the State.

The management of grasslands, locally known as—*birs*, consists of closure during rains and grass cutting during winter. The areas are thrown open to cattle during the summer after the cutting operations are complete. Certain areas also require seeding with edible grass species such as *Cenchrus ciliaris*, *C. setigerus*, *Lasiurus sindicus*, *Sehima nervosum*,

indica, Calotropis procera, Suaeda fruticosa and *Salsolia foetida* are found. Ravine areas along Chambal, Banas and other rivers are heavily grazed and contain an open crop of *Prosopis spicegera, Salvadora oleoides, Balanites aegyptica, Acacia catechu*, etc.

Tree Savannahs : Scattered grasslands occur over a wide area, though forming a small percentage of the forest area. These are important reserves of fodder for the cattle.

The naturally occuring grass types in the State are : *Lasiurus indicus-Cenchrus* and *Lasirus-Cymbopogon* types in arid tracts, *Schima-Dicanthium* and *Cymbopogon* types in semi-arid tracts, *Dicanthium-Cenchrus* type in transition zones of arid and semi-arid, and *Themeda-Pseudanthistiria* and *Themeda-Pennisetum hohenackeri* types in sub-humid zones. From the point of view of fodder, *Lasiurus indicus, Sehima pervosum, Dicanthium annulatum, Cenchrus ciliaris, Cenchrus setigerus* and *Pannicum antidotale* form the most important grasses.

The tree vegetation in grasslands is sparse consisting of *Acacia leucophloea, Balanites aegyptica, Dictrostachys cinerea, Capparis decidua, Zizyphus xylopora* and *Prosopis spicigera*. The undergrowth consists of shrub and grass cover.

III—Major and Minor Forest Produce

1. *General*

A large proportion of the State forests lies in the arid zone and supports open scrubby vegetation. The southern and south-eastern part east of Aravalis is well wooded and contains better quality forests, though timber species are, as a whole, deficient. The main forest produce is the dhauk wood *(Anogeissus pendula)* which is used principally as firewood and for manufacture of charcoal. Some poles and small timber is obtained from teak and other species, viz. *Terminalia tomentosa Prosopis spicigera, Tecomella undulata*, etc., while packing case species are *Boswellia serrata, Lannea coromandelica*, etc.

Amongst the minor forest products, katha, khas oil, tendu leaves and grass are the most important items. Katha (Catechu) is extracted from *Acacia catechu* heartwood and manufactured by the traditional method. Khas oil is distilled from *Vetiveria zizinoides* which is found mainly in Bharatpur and Tonk Forest Divisions. Several secondary species, viz. haldu *(Adina cordifolia)*, al *(Morinda tinctoria)*, selar *(Boswellia serrata)*,

wood requirements of local population is considerable. Unfortunately, a good proportion of otherwise valuable forests, including the teak forests, have been considerably degraded by maltreatment in the past, intensive biotic pressures and indiscriminate utilisation.

2. *Soil Conservation*

Soil erosion is a serious problem in three important tracts, viz. (i) desert areas, (ii) hilly tracts suceptible to erosion and (iii) ravine lands.

In desert areas, the shifting sand dunes threaten large areas and their stabilisation is imperative for soil conservation. This can be best done on an ecological basis by introduction of pioneering species initially and added by mechanical devices such as fixing brushwood material in chess board pattern. Direct seeding of small shrubs and grass species followed by introduction of indigineous and exotic tree species like *Acacia senegal*, *Prosopis juliflora*, *Tecomella undulata*, *Zizyphus jujuba*, *Eucalyptus oleosa* and *Acacia tortillis*, shrubs such as *Calligonum polygonoides*, *Cassia auriculata*, *Ricinus communis* and grasses like *Lasiuris hirsutus*, *Panicum antidotale*, *P. turgidum*, *Erianthus munja* holds promise in the stablisation of dunes.

In the hilly tracts, the problem is mainly of soil erosion due to lack of cover, and stony and rocky nature of soil. Soil conservation works consisting of contour trenching and check dams and loose stone fencing over about 29,960 ha have been carried out so far.

3. *Ravine Reclamation*

The ravines occur extensively in the eastern and south-eastern parts of the State along the Chambal, Mahi, Banas, Kalisindh and Sabi rivers and cover nearly 3,23,749 ha. The reclamation of the ravines to arrest soil erosion and reclaim the land for grasslands, afforestation, etc. are problems of magnitude on account of the large area involved. A survey of the ravine areas has already been carried out and afforestation works have been taken up over 1460 ha. during the Third Plan. The existing plantations have shown that *A. arabica*, *Prosopis juliflora*, *Albizzia lebbek*, *Ailanthus excelsa*, *Azadirachta indica* and bamboos give good results in ravine areas. Other species which can be tried in such areas are

Apluda mutica, *Dicanthium annulatum* and *Themeda quadrivalvis*. The yield of air dried grass from grass reserves usually varies from 200 to 600 Kgm per acre. With proper management, like restricted grazing, contour furrowing and use of fertilizers, the yields can be increased severalfold.

Such species of trees as provide for fodder, e.g. *Anogeissus pendula*, *Bauhinia racemosa*, *Butea monosperma*, *Ailanthus excelsa*, *Azadirachta indica*, *Ficus* spp., *Prosopis juliflora*, should be encouraged wherever present or introduced.

3. *Wild Life*

A rich natural recreational resource is the wild life and a number of wild animals and birds are found in the State. Amongst the animals tiger, panther, sloth bear, gazelle, four-horned antelope, black buck, sambar, wild-bear, pangolin, otter and wild dog are fairly common. A variety of reptiles like crocodiles, cobra, rat snakes, kraits, monitor lizard, snake fish, etc., is also found.

The bird life is more interesting and a variety of birds, both migratory and others, occurs in the State. Common amongst the birds are the bulbuls, the common babbler, fly-catchers, Indian robin, king fishers, woodpeckers, blue rock-pigion, larks, shrikes, grey hornbill, golden oriole, and purple sunbirds. The migratory species include whistling teals, bar-headed goose, pintails, pochards, flamingoes, floricans shovellers, demoiselle cranes, rosy and grey pelicans and the Siberian cranes.

There are at present eight wild life sanctuaries in the State including the famous bird sanctuary at Ghana which attracts a large number of tourists every year.

IV—IMPROVEMENT OF FOREST RESOURCES

1. *General*

The forest resources of Rajasthan though not much of economic significance at present are nevertheless of great importance in the development of arid regions. Their importance as stabilisation agency in sandy arid tracts, protective cover on catchments, soil conservation in ravines, sources of fodder and grazing, and above all in meeting the

6. *Farm Woodlands*

The creation of farm forests in village wastelands would cater to the fuel wood and small timber requirements of village population and reduce pressure on existing forests. A beginning was made in the 2nd Plan on such a scheme by taking up farm woodland afforestation in Panchayat lands. Such schemes need be extended in spite of initial hurdles, over larger areas with provision of adequate funds. The depleted forests of Panchayat Samiti areas can also be rehabilitated under this scheme by cutting back and tending operations.

7. *Grassland Management*

The degraded forests and the grass reserves need development for forage production. In the grasslands (birs) reseeding with suitable grasses like *Cenchrus ciliaris, C. setigerus, Lasiurus indicus, Dichanthium annulatum, Sehima nervosum, Iseilima wightii* and *I. laxum* by fencing and contour furrowing would improve the grass reserves. If necessary, in poor areas the seeding can be done along with the application of fertilizers to hasten growth. The unpalatable trees and shrubs like *Capparis decidua, Calotropis procera, Tephrosia purpurea, Leptodenia pyrotechnica, Datura* sp. require to be eradicated. Top feed species like *Prosopis spicigera, Ailanthus excelsa, Zizyphus mauritiana, Z. nummularia, Acacia nilotica* need also to be introduced in the grass reserves wherever possible. As far as possible, deferred and rotational grazing should only be allowed according to the capacity of the area.

The existing production of grasses from grass reserves is poor, viz. about 200 Kgs per ha, and with suitable management practices it should be possible to obtain about 500 kg per ha of grass production.

8. *Minor Forest Produce*

In addition to the improvement in existing minor forest products, a number of medicinal plants can be introduced in suitable localities as there is very little production of medicinal plants at present. The suitable species which can be introduced in the dry tracts are *Datura stramonium, D. innoxia, Glycorrhiza glabra, Cassia acutifolia, C. angustifolia, Commiphora mukul, Ephorbia resinfera* and *Acacia senegal.*

Acacia catechu, Albizzia amara, Balbergia sisso, and suitable species of *Eucalyptus.* In view of the large area of ravines, the afforestation programme in association with soil conservation measures needs to be speeded up.

4. *Rehabilitation of Degraded Forests*

As already stated earlier, a large tract of forest area is degraded due to maltreatment and includes the 'danda kasht' or shifting cultivation, the degraded jagir forests, and other types of degraded forest areas. It is estimated that a total of 28,40,400 ha of such forest area is in the need of rehabilitation, out of which nearly 59581 ha has been covered during the Third Plan. The rehabilitation of degraded forests can be done by cutting back of the malformed growth, tending new crop and planting up gaps. Rehabilitation work on these lines on the potential valuable teak areas has given encouraging results. It is also necessary to protect these areas from grazing damage by voluntary closure through public education and publicity on the importance and benefits of forests. Such measures shall go a long way in recouping the poor tree cover and ameliorating the economy of the rural areas to an appreciable extent.

5. *Economic Plantations*

There is a restricted scope of raising economic plantation due to poor soil and severe climatic conditions. However, some areas like irrigated canal banks, and better types of areas can be planted with valuable industrial and commercial species like teak, *Ailanthus excelsa, Salmelia malabarica, Holoptelea integrifolia, Eucalyptus hybrid, Acacia catechu, Dalbergia sissoo* and bamboos *(Dendrocalamus strictus).* So far nearly 7900 ha of economic plantation of teak, *Boswellia serrata,* babul, mulberry and *Eucalyptus* plantations have been raised during the third plan. Irrigated plantations of mulberry *(Morus alba), Dalbergia sissoo, Eucalyptus camaldulensis, Eucalyptus tereticornis* also hold promise due to the coming up of Rajasthan canal. For this purpose, the species for different sites over the concerned area have to be carefully selected with respect to soil type, drainage and other micro-situ condition to derive maximum benefit from irrigation.

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9. *Wood-based Industries*

So far as large scale wood-based industries are concerned their prospects in Rajasthan are limited. However, there is scope for the establishment of a chip board factory near Banswara utilising teakwood from degraded stock. *Boswellia serrata* and *Lannea coromandelica* are species which occur in good proportion and are suitable for packing cases and pulp. Roonjh *(Acacia lucophloia)* is useful for manufacture of gunstocks and occurs widely in forests and westelands. A number of grasses occuring in the State, viz. *Apluda mutica, Themeda quadrivalvis, Sehima nervosum, Heteropogon contortus* are suited to the manufacture of straw boards and a strawboard factory has already been set up at Kota.

V—Conclusions

Though at present the forest resources of Rajasthan are limited, there is considerable scope for their development and improvement provided sustained cooperation from the public is available at all stages. Universally true as this may be, it is of special significance to a State like Rajasthan, where climatic and edaphic conditions are very severe and inhospitable to the vegetation, and specially tree growth. Furthermore, the socio-economic welfare of the people and the protection and fertility of agricultural lands are intimately connected with the maintenance of adequate tree cover in vulnerable areas. Therefore, the protective and functional role of forests and other vegetation should have priority over material benefits from forests accruing to the local people. Simultaneously with this over-riding principle, concerted efforts have to be made to raise the economic level of the people by various measures of which production forestry including improvement of pastures and grazing can form an important plank.

production from these forests is rather limited in terms of fuelwood and timber, yet the protective and functional role of these forests is of great significance. Equally important is the provision of grazing and fodder from these forests and other lands which have to support about 10% of the total cattle population of India. Cattle rearing and farming is an important aspect of the socio-economic structure of the State which contributes nearly 45% of the country's total wool production. Consequently, proper management of grazing and improvement of grazing lands and pastures is as essential as proper protection and maintenance of forests, as both these aspects have a direct bearing on soil and moisture conservation which is of paramount importance to the State. Some suggestions in these respects have been given.

Other benefits from forests include the provision of fuelwood and small timber to the local people. In this respect, the scheme of development of farm forests and village woodlands needs to be intensified. Also, with the coming up of Rajasthan Canal, there are good prospects of irrigated plantations of economic species in Rajasthan. Forests also provide a number of minor forest products, particularly gums, bidi leaves, bomboos and medicinal plants. More attention has to be paid on their development as well.

As far as large scale forest based industries are concerned, their prospects are limited in Rajasthan. However, there is scope for the establishment of a Chip-board factory near Banswara, utilising teak-wood from degraded stock. A straw board factory has already been set up at Kota, utilising a number of grasses.

In conclusion, the dual role of forests-protection and production has been emphasised, the former having predcedence over the latter. For all forest developmental activities, the sustained cooperation of the local people is a pre-requisite, particularly in a State like Rajasthan where the climatic and soil conditions are inhospitable to vegetation.

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THE ROLE OF NON-TIMBER FOREST PRODUCTS IN RAJASTHAN'S ECONOMY

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I—INTRODUCTION

Rajasthan's forests produce a fair quantity of timber especially of the smaller kind. Poor though the scrub forests look, they actually abound in numerous species of economically important plants which can yield *their* major products, namely, the non-timber products, which elsewhere go under the name 'minor forest products.'

Rajasthan presents a vast contrast in vegetation. The forest areas are open and degraded on denuded hilly terrains. Extremes of site factors have resulted in variable vegetation from scrubby and thorny bushes on sand dunes in north-west to the dense green forests, rich in wild life in the south and the semi-evergreen forests of Abu Hills.

India earns considerable foreign exchange by export of non-timber forest products, which amounted to 40 to 80 crores of rupees annually during the past three years as against 3 to 6 crores worth of timber (Rao, *et al.* 1968). Rajasthan's share of these earnings can be considerably enhanced through proper organization of the technical aspects of production as well as of marketing.

In the following few pages are described the various categories of these economic forest products. For convenience the species have been classified as below according to the nature of their utilization except the medicinal plants which will find separate entity in this symposium :

1. Gum and resin-yielding species
2. Tan and dye-yielding species
3. Cutch and Katha
4. Oilseeds and oil-yielding plants
5. Essential oil bearing plants
6. Species providing fibres and flosses, material for mats, ropes, huts, brooms and paper

7. Bamboos
8. Species providing miscellaneous products, viz. Wax, Bidi leaves, etc.
9. Edible products species

II—GUM AND RESIN-YIELDING SPECIES

This group of species fetches sizeable revenue to the State which was estimated to the level of Rs. 3.16 lakhs in 1961 and utilization of the produce was assessed to be Rs. 7,01,329 in 1964-65 in Rajasthan. The species are given below :

1. *Acacia nilotica* ssp. *indica* Willd. (Babul) yields babul gum and occurs as a common species in tropical forests. The spontaneously exuded gum alone is generally collected locally.

2. *Acacia catechu* (Linn.) Willd. (Khair) is utilized for the extraction of katha.

3. *Acacia senegal* Willd. (Kher) is a shrub-like low tree which yields gum arabic, and is one of the best species of gum-yielding Acacias.

4. *Anogeissus latifolia* Wall. (Dhaura) yields gum *ghatti* or *dhaura gum* of commerce, and is used for calico printing and in pharmaceuticals and ceramics. The gum is collected locally in summer when it copiouly oozes out from the trees. The trees, however, are not tapped for gum at present.

5. *Boswellia serrata* Roxb. (Salai or Salar) is an important source of gum-oleo-resin called salai gum or 'Indian oblibanum'. It seems this species has not yet been tackled to obtain gum-oleo-resin in Rajasthan.

6. *Commiphora wightii* Engl. yeilds a fragrant gum-oleo-resin, called 'Indian myrrh' (Indian bdellium or guggul), used as an incense, as a fixative in perfumery, in medicine and as a substitute for the foreign myrrh. Guggul is collected in cold season by making incisions on the trunks of trees.

7. *Lannea coromandelica.* (Hout.) Merr. (Jhingan) yields Jhingan gum of commerce and is probably not being tapped so far in Rajasthan.

8. *Sterculia urens* Roxb. (Kada) yields gum karaya and ranks second to gum arabic in commercial importance in world trade. It has a very high export potential.

In addition to the above, a few other species, viz. *Acacia leucophloea* Willd., *A. jacquemontii* Benth., *Butea monosperma* (Lam.) Taub. and *Prosopis juliflora* may also be tried to obtain gum. The bark of *Soymida febrifuga* A. Juss. also exudes a gum which makes a good adhesive.

III—TAN AND DYE-YIELDING SPECIES

There appears to be far greater scope in Rajasthan for the species which yield tannin and dyestuff materials. They were estimated in 1961 to yield the revenue of Rs. 1.57 lakhs in Rajasthan. Some of the species which are considered useful for tanning and dyeing purpose are listed below with brief notes.

1. *Acacia nilotcia* (Lam.) ssp. *indica* Willd. (Babul). Bark and pods of this species are used as tanning material. Bark contains 12% tannin and the tannin content varies from 12-19% in the entire pods and 18-27% after the removal of the seeds. It is a prodominant tanning material in northern India.

2. *Acacia leucopholea* Willd. It is a common species growing in dry parts. The average tannin content of bark is about 12 per cent. It is also used by users of babul bark.

3. *Anogeissus latifolia* Wall. (Dhawa). This species occurs in plenty in Rajasthan. Its leaves (sumac) and bark are used as tanning material. Tannin content of leaves varies from 22-46% while in bark the average tannin per cent is 13 only, and sumac (a special preparation of crushed leaves) is the richest tanning material.

4. *Bauhinia purpurea* Linn. (Koliar). Its bark is used as a tanning and dyeing material. It occurs as one of the common associate species in the sub-tropical evergreen forests of Rajasthan.

5. *Carissa opaca* Stapf. (Karaunda). This is an evergreen shrub of the sub-tropical evergreen forest of Rajasthan. The average tannin content of mature leaves is estimated at 11%. Karaunda is unusual in that the quite young leaves contain no tannin, which, however, increases as the leaves mature. This is unusual and contrary to other tannin leaves.

6. *Cassia fistula* Linn. (Sonari). It is commonly known as Indian laburnum and is used for tanning purpose as commonly as avaram bark. It cotains about 12% tannin and is used as a diluent for avaram whenever its price is less than that of avaram, proportionate to its tannin content. Its occurrence is common in the *Anogeissus pendula* type of forest of Rajasthan.

7. *Soymida febrifuga* A. Juss. (Rohun). Bark of this species contains about 13-14% tannin and is used for tanning and dyeing. It gives a dirty brown colour to cotton fabrics. It occurs in the dry teak forest and mixed deciduous forest of Rajasthan. In the latter this species occurs on the plateau and gentle slopes with poor soils.

8. *Terminalia arjuna* Bedd. (Kahua). It occurs very commonly along nallas in the dry teak forests of Rajasthan. The bark of the lower branches contains 18% tannin as against 20-24% for the bole bark. It is an advantage that Kahua bark can be repeatedly cut and it will grow again to produce new layers of bark. It is commonly used by the tanners and needs attention of the foresters for greater exploitation.

9. *Terminalia bellirica* (Gaertn.) Roxb. (Bahera). It grows as one of the main species in the mixed deciduous forests of Rajasthan. Fruit, bark and wood of this species contain tannin but except for its fruits, commonly known as beleric myrobalan, others are not worth consideration due to their insufficient tannin content. Beleric myrobalan contains about 24% tannin and is very commonly used by the tanners of India as an important mixture with other tanning materials.

10. *Terminalia tomentosa* W. & A. (Sain). This is a large deciduous tree occurring as one of the common associates of dry teak forest and mixed deciduous forest of Rajasthan. Its bark is of importance as tanning material, but the outermost layer of bark contains no tannin and should be removed in collecting the bark.

11. *Ziziphus xylopyra* Willd. (Gothar). This is found scantily in the dry teak type of forest of Rajasthan but wherever it occurs its fruits can be utilized as tanning material which contains 16-21% of tannin. Gothar fruit has long been used by village tanners with success. This species is also of some value for re-foresting poor soils. This property can be taken advantage of in the reforestation programme.

12. Balanites aegyptiaca (Linn.) Delile (Hingan). This species occurs as an undergrowth in *Anogeissus pendula* forest and as common species in tropical thorn forest, and its fruits are used as detergent for silk.

13. Butea monosperma (Lam.) Taub. It yields yellow to orange flower dye. Area under this species is approximately 565 sq km in Rajasthan.

14. Nyctanthes arbor-tristris Linn. (Harsinghar). It occurs in Rajasthan as an undergrowth. Orange coloured tubes of flowers of this species give orange or golden yellow dye for colouring liquors.

15. Mallotus philippensis Muell. Arg. It occurs in the valleys of the sub-tropical evergreen forest and yeilds a fruit dye, 'Rottlerin' which is used for dyeing silk. It gives an orange or flame colour to oils, soaps, ice-creams and drinks.

16. Wrightia tinctoria R. Br. It yields an indigo-like blue colouring substance from leaves. It occurs rarely in the dry teak forest of Rajasthan.

In addition to the above existing species, *Haloxylon ammodendron* Boiss. is recommended for green dye and *Lawsonia inermis* Linn. which yields '*henna*' dye of commerce, as worth propagating in Rajasthan. The latter gives an orange dye for fabrics, leather, hair, eye-brows, finger nails and personal adornment and can enjoy good possibilities in the foreign market.

IV—Oil-Seeds and Oil-yielding Plants

1. Balanites aegyptiaca (Linn.) Delile. This species occurs as an undergrowth in *Anogeissus pendula* type of forest as one of the common species in tropical thorn forests. It is a small thorny tree growing in drier parts of India, and in Dungarpur and Kota-Shahbad of Rajasthan. A fixed oil called 'zachun' is extracted from seeds (Puri and Jain, 1960). In Rajasthan the pulp of the fruit is used for washing silk as it contains *saponin*. The empty woody shell after removing the seed through a small hole is made into crackers for local fire works.

2. Mallotus philippinensis Muell. Arg. (Kamala). This species is quite common in the valleys of the sub-tropical evergreen forests of Rajasthan. About 270 quintals of seeds are produced annualy. The seed cotains about 35 per cent oil. The oil has been recommended for

use in the preparation of air drying wrinkle-finish varnishes and paints. It has also been used for the preparation of oil modified alkyd resins which on baking set to wrinkle patterns and smooth coatings and spar varnishes. The seed cake left can be used for manurial purposes. It seems profitable to undertake large-scale trials with regard to extraction, storage and application of Kamala seed oil.

3. *Pongamia pinnata* (Linn.) Pierre (Karanja). This species occurs in the valley and along streams where soil is deep and rich in the mixed deciduous type of forest of Rajasthan, paticularly in Gujaner, Ankaleshwar, Bhuj and Junagad Datar hills. A useful oil, known in some places as honge oil, is extracted from the seeds. It is useful as a luminant oil and also as insecticide against coffee green bug especially for its insecticidal properties, as also for insecticidal soap making.

4. *Ricinus communis* Linn. (Castor oil plant or Arandi). It is a species which is likely to do well in Rajasthan and is therefore recommended for cultivation in available forest areas besides agricultural land. This is one of the most valuable oilseed bearing plants. Its seeds contain a high percentage of oil and also a blood coagulating toxin 'ricin' and enzyme lipase. Arandi oil is highly valuable both medicinally and industrially. The oilcake left after the extraction of oil is a valuable fertilizer (Dastur, 1954).

5. *Semecarpus anacardium* Linn. It is reported to be occurring in Jajhra area of Rajasthan. The oil extracted from seed is used as a wood preservative against attacks of whiteants and as a lubricant for wooden-axle carts. In addition to this, the caustic juice contained in the rind of fruit has many medicinal, domestic and industrial uses. It is a powerful irritant and vesicant and causes dermatites. The juice is used for marking linen indelibly. It has recently been shown that this juice can be converted into non-vesicant products which can be commercially used for making lacquers, varnishes, enamels, synthetic tanning materials, insulating materials and moulding plastics.

6. *Terminalia bellirica* Roxb. It occurs in the same localities of Rajasthan as *Pongamia pinnata* particularly in Banjoi. After utilization of the pericarp, the seeds can be used for the extraction of oil which is used as a hair oil.

Some of the above species are suggested for proper utilization in the State, though commercial utilization of the fatty oils from the seeds of Indian forest plants is beset with several difficulties, viz. irregularity in the annual fruiting of trees, tediousness in the collection of seeds, ripening of some seeds in beginning of monsoon which renders the seeds liable to fungus attack and deterioration of the oil content on account of humidity, uneconomic oil content (below 25%) for expression purpose and lack of cheap industrial solvents for extraction of oil. It is, therefore, worth investigating these factors before taking up the extraction of oil (Puntambekar, 1952).

V—ESSENTIAL OIL-BEARING PLANTS

1. *Boswellia serrata* Roxb. (Salai or Salar). This species occurs in the upper ridges of the Aravalli hills in almost pure patches in *Boswellia serrata* type of forests and also in Dungarpur, Panchkund, Sawai Madhopur and Kota-Shahbad. The essential oil obtained form the exudates from the stem and branches and called 'olibanum' consists of an essential oil which can serve as a substitute for the American pine turpentine and is used in preparation of quick-drying varnishes and paints.

2. *Cyperus rotundus* Linn. (Nagur motha). It occurs throughout India and in Rajasthan in Gujaner. It is a perennial sedge with reddish-brown branched umbelliform spikes. The useful part of the 'grass' is rhizome which is spongy, aromatic, resinous and balsamic which yields an essential oil. This oil is used in perfumery and for soap-making and as insect-repellant.

3. *Eucalyptus* spp. There appears to be a wide scope for growing eucalyptus in the sub-tropical evergreen forest of Rajasthan as it is reported that *Eucalyptus* species introduced in Rajasthan are doing well. Species worth trying are *Eucalyptus citriodora* Hook., *E. fruticetorum* F. Muell (*E. polybractea* R.T. Baker), and Mysore gum species comprising *Eucalyptus tereticornis* Sm. and *E. camaldulensis* Dehn.

4. *Michelia champaca* Linn. (Champa). This species occurs in Mount Abu and the champaca oil of commerce obtained from its flowers is used in perfumery. The oil contains iso-eugenol.

5. *Rosa moschata* Herrm. This species occurs in the sub-tropical evergreen forest of Rajasthan and it is worth trying to obtain oil of rose which gives clove like odour.

6. *Vetiveria zizanioides* (Linn.) Nash. It is wild all over India and is exploited in Bharatpur for Khus-khus oil. It was assessed to have been utilized to the level of about Rs. 20,000 in 1964-65. The commercially important part of this grass is its roots which yields khus-khus oil. It is one of the most viscid of essential oils and is therefore in great demand for fixing volatile perfumery oils. Oil usually distilled in Bharatpur is of the heavier type and is generally used for high class soaps.

In addition to the above species occurring in different forest types of Rajasthan, cultivation of a few of the following species is worth taking up in Rajasthan State.

1. *Acacia farnesiana* Willd. (Vilayati-babul). For cassia perfume, distilled from the flowers. It has a commecrial importance.

2. *Andropogon laniger* Desf. Tufted grass with aromatic roots.

3. *Bursera delpechiana* Poiss.ex Engl. This species is suggested for trial. The berries and wood of this tree yield the 'linaloe oil' of commerce. The oil is a valuable perfumery material.

4. *Cymbopogon martini* (Boxb.) Stapf var "Motia" and "Sofia." Flowering top and leave of these two varieties of grass yield palmarosa oil or Rosha grass oil and ginger oil of commerce respectively. Export of palmarosa and ginger grass oil ranged from 17 to 38 tonnes and about one tonne respectively during the last three years (1964-65, 1965-66 and 1966-67). This grass can afford good prospects for establishment of Essential Oil Industry in Rajasthan.

5. *Cymbopogon nardus* (Linn.) Rendle. This grass yields Ceylon citronella oil of commerce which is chiefly used in the scenting of soap and several technical preparations and as an insect-repellant.

6. *Cymbopogon winterianus* Jowitt. This grass is closely related to *C. nardus* and yields Java citronella oil of commerce.

7. *Mentha arvensis* DC. This needs special attention as the Japanese mint oil is an important source of natural menthol largely used in medicine which is imported to the tune of about 20 to 63 tonnes annually to meet our requirement.

8. Mentha piperita Linn. This is also required to be cultivated on large scale as the peppermint oil which is obtained from the leaves and stem of this species is one of the most important essential oils used for medicinal and flavouring purposes (Badhwar *et al.*, 1964). India imports about 55 to 90 tonnes annually to meet the requirement of the country.

9. Ocimum kilimandscharicum Guerke. The volatile oil obtained from the leaves is a valuable source of camphor and camphor oil.

10. Pandanus tectorius Soland. Though common in the tidal forests of Sunderbans on the sea coast of south India and backwater canals of Travancore and Andamans, it can also be grown in the dry and desert areas. The flowers of this species yield keora oil of commerce which is chiefly used to flavour katha and catechu. Keora attar is of value to perfumers. It enjoys an export trade.

11. Santalum album Linn. (Chandana, Sandal). This is found introduced from south India in small patches in some parts of Chittorgarh, Jhalawar and Banswara forest divisions, mainly on Deccan trap. The most common host plant is *Carissa spinarum*. Though natural regeneration in seedling and sapling stages is reported to be plentiful, trees above 10 cm diameter at breast height are scarce (Srivastava and Mathur, 1964). The exploitable diameter is fixed at 30 cm d.b.h. and it has been prescribed in the working plans to protect the trees. The most valuable part of the wood is its inner part, the heart wood which contains sandalwood oil of commerce. The heart wood development in north Indian locations is still to be studied as it seems to be generally slower. No substantial quantity of sandalwood oil has yet been obtained from sandal grown in northern India.

VI—SPECIES PROVIDING FIBRES AND FLOSSES

This group of plants earns a considerable amount of foreign exchange for our country and during the past three years India's export of fibres and flosses, barring cotton and jute, ranged from Rs. 554 to 850 lakhs annually. Some of the species are listed below with brief notes on their utilization.

1. Bauhinia purpurea Linn. This species yields a fibre, but the fibre obtained from *B. vahlii*, called 'Malu' fibre, and *B. racemosa* are more useful.

2. *Butea monosperma* (Lamk.) Taub. Fibre is extracted from bark and roots of this species. It is used for making cordage and paper, and for caulking boats; in villages the fibre is converted into slow matches. The leaves are made into plates and umbrella coverings; they are also used for thatching, wrapping "bidis" and as a substitute for wrapping paper.

3. *Calotropis gigantea* R. Br. and *C. procera* R. Br. (Madar). The valuable fibre, bowstring hemp of India, is extracted from this species. It is a fine, strong, silky fibre, with properties of flax. The fibre can resist the action of fresh or salt water. It is woven into cloth and used for making sewing thread, bow-strings, carpets, ropes, bird and fishing nets, fishing lines, nooses and tiger traps. The silky floss obtained from seeds is used for stuffing pillows. This species occurs in the tropical thorn forest of Rajasthan.

4. *Crotalaria burhia* Ham. The important produce of this shrub is its fibre. It is used for cordage, coarse gunny cloth and canvas. Other species also yield a fibre called "sann" of similar utility. This species occurs in the sandy soils of tropical thorn forest of Rajasthan and is easily regenerated by root suckers.

5. *Girardinia heterophylla* DCNE. (Nilgiri nettle). It is a tall, stout, course, erect herb which occurs on the slopes of Mt. Abu in the sub-tropical evergreen forests of Rajasthan. It yields a strong, durable, soft, beautifully white and silky fibre, 15-50 cm long, resembling ramie fibre *(Boehmeria nivea)* or flax *(Linum usitatissimum)*, though it is coarser and less lustrous. It is rich in cellulose and resists the action of alkali. It is suitable for making gunny bags, coarse cloth and similar articles. It may take a high place amongst textile fibres.

6. *Pandanus tectorius* Soland (Keora, Screw pine). Leaves and roots provide useful material. The leaves are woven into mats, sugar-bags, umbrellas and hats. They are used for thatching and for paper making. A valuable fibre is also obtained from the leaves which is made into cordage, fishing nets, fishing lines, hunting nets, brush bristles and sacking. The fibrous aerial roots are used for tying baskets, and for making mats, baskets, hats, brushes for white-washing and painting.

7. *Soymida febrifuga* Adr. Juss. (Indian Red wood, Rohun tree, Lal chandan). This occurs in Rajasthan at places as indicated earlier

and the bark of this species yields a red fiber which is used for making ropes.

8. *Grasses* : Amongst the various grasses growing in dry teak type of forest, *Boswellia serrata* type of forest and tropical thorn forests of Rajasthan, only *Elyonurus hirsutus* (Vahl.) Munro is important from the fibre point of view, while others are used as fodder grasses in Rajasthan. This grass grows abundantly in depressions and shallow valleys on lime stone and is also a good fodder (Puri and Jain, 1960). The root fibre of this species is used as weaver's brushes. A few other grasses are listed below with brief notes on their utilization as fibre material, these grasses can be grown in dry and desert areas successfully.

1. *Aristida setacea* Retz. Grass for screens and brooms.

2. *Arundinella setosa* Trin. Grass for brooms.

3. *Desmostachya bipinnata* Stapf. (*Eragrostris cynosuroides* Beauv.). Good grass for thatching, ropes and mats and as a mixture for paper-pulp.

4. *Eulaliopsis binata* Retz. Hubbard (*Ischaemum angustifolium* Hack.). Good for paper making, ropes, mats and baskets.

5. *Imperata cylindrica* (Linn.) P. Beauv. (*I. arundinacea* Cyrill). Useful for thatching and paper-making and stuffing pillows.

6. *Saccharum ciliare* Anders. Suitable for thatching, matting, basket and screens.

7. *S. munja* Roxb. Yields commercial *munj* fibre used for making baskets, mats, cordage and ropes; leaves for thatching and paper-making.

8. *Vetiveria zizanioides* (Linn.) Nash. Fine root fibres are woven into baskets and curtains "tatties". Grass can be processed to give pulp for straw board.

The grasses available in Rajasthan have been found most suitable for manufacture of pulp. It was planned in 1964 to establish two units during the five years for the manufacture of pulp and card-board. A straw board factory has been established at Kota and a variety of fodder grasses of Rajasthan State, viz. Polarda (*Apluda mutica* Linn.), Raterda (*Themeda quadrivalvis* O. Kuntze), Gandhel (*Sehima nervosum* Rotl. Stapf) and Soorwal (*Heteropogon contortus* Linn.) P. Beauv which are well suited for the manufacture of straw-board may be used (Anon., 1968).

VII—BAMBOOS

Dendrocalamus strictus Nees is the only bamboo which occurs in the forests of Rajasthan covering an area of 940 sq km mainly in the dry teak and dry mixed deciduous forests. It generally forms pure patches in moist depressions as well as with main associate species. It is usually found in the understorey but sometimes in the upper canopy as well. Bamboo forests occur mostly in parts of Chittorgarh, Udaipur, Kota, Banswara divisions, and on Abu hills. Bamboo forest covers about 2.5 per cent of the total area of Rajasthan. The cutting cycle for the exploitation of bamboo forests is prescribed from 3 to 4 years in which selective fellings of not less than 2 year old culms is permitted.

D. strictus is an important minor forest produce in the State and roughly about 120 lakhs of bamboos are annually exploited from the forests. Revenue of Rs. 5.48 lakhs can be obtained from bamboos in Rajasthan. It was assessed during 1964-65 that bamboo was utilized to the level of Rs. 11,04,796 in Chittorgarh, Udaipur, Bharatpur, Ajmer, Kota, Baran, Jhalawar, Banswara and Sirohi. Some of the bamboos are locally used for basket-making, curtains (chicks), fencing, house construction, carpets, furniture, toys and lathis, and the rest is exported outside the State. There is possibility of utilizing surplus bamboo with *Salai* for paper production.

VIII—SPECIES PROVIDING MISCELLANEOUS PRODUCTS

1. Bidi leaves. Leaves of *Diospyros melanoxylon* Roxb. (Tendu) are used for manufacturing 'bidis'. It occurs abundantly in admixture or even in small pure patehss almost all over in the forests of the State. Leaves are generally collected from 1st March to 30th June. Fresh leaves are of much value for bidi wrappers. It was estimated in 1961 that the revenue of Rs. 1.50 lakhs was obtained from bidi leaves in Rajasthan and in 1964-65 bidi leaves were utilized to the level of Rs. 7,83,192. Leaves of *Bauhinia racemosa* Lam. which occurs in the dry teak forests can also be utilized for bidi wrappers.

This is a developing industry giving employment to thousands of people, right from plucking of leaves in the forest to the manufacture of bidis. In the adjoining State of M.P. the work has now been taken up departmentally and a corporation has been organized. Rajasthan

State can similarly develop, as within a short period the revenue has multipled five times in Madhya Pradesh.

2. *Honey and wax.* These products are already being exploited in Chittorgarh, Udaipur, Jodhpur, Bharatpur, Ajmer, Kota, Baran, Bundi, Jhalawar, Banswara, Sirohi, Jaipur and Tonk, and during the year 1964-65 utilization of the produce was assessed to be Rs. 70,795. It was estimated in 1961 to yield the revenue to the tune of Rs. 0.44 lakhs in Rajasthan.

In addition to *Cocos coronata* Mart. which occurs as an introduced species in Rajasthan, *Euphorbia antisyphilitica* Zucc. can also be introduced and exploited for candelilla wax which is a substitute for carnauba wax. Wax on leaves of *C. coronata* is a very important cheap substitute for carnauba wax for shoe polishes and for making carbon paper.

Euphorbia antisyphilitica is a native of north-eastern Mexico and can be grown in a desert-like area where annual rainfall may be less than 100 mm. Wax occurs in a thin film on the stems which is recovered by boiling with water or by extraction with petroleum spirit. Harvesting and wax extraction is usually carried out in winters, when the plant's supply of wax is at its peak. If fields are allowed a partial rest every 3 to 4 years a stand will continue to produce for 12 to 16 years.

3. *Fodder grasses.* It has been estimated that a revenue of about 11.88 lakhs of rupees can be obtained from the grasses and the utilization of the produce as assessed in 1964-65 was to the level of Rs. 6,76,246 in Rajasthan. Hence grasslands for fodder supply for cattle and sheep may be maintained side by side on restricted patches, with suitable rotation and management. A list of grasses available for fodder in Rajasthan is furnished below :

(i) *Apluda* sp. Common in dry teak forests and *Boswellia serrata* and tropical thorn forests.

(ii) *Aristida hystrix* Linn. It occurs in dry teak forests.

(iii) *Cenchrus ciliaris* Linn. It occurs in tropical thorn forest.

(iv) *Dactyloctenium sindicum* Boiss. Found in tropical thorn forest and esteemed as desert fodder.

(v) *Dicanthium annulatum* (Forsk.). Stapf. (*Andropogon annulatus* Forsk.). It is suggested to establish this grass for fodder through transplanting of rooted slips in Jodhpur.

(vi) *Elyonurus hirsutus* (Vahl.) Munro. A desert fodder of tropical thorn forest.

(vii) *Eragrostris* sp. Found in fairly deep soil of *Boswellia serrata* type of forest.

(viii) *Heteropogon contortus* (Linn.) P. Beauv. Found in dry teak and *Boswellia serrata* type of forests and is esteemed as fodder grass in desert areas.

(ix) *Panicum antidotale* Retz. and *P. turgidum* Forsk. Found in tropical thorn forest and the latter is esteemed as camel fodder.

(x) *Sehima nervosum* (Rotl.) Stapf. Found in dry teak forest and is said to yield an excellent fodder.

(xi) *Themeda quadrivalvis* O. Kuntze. Found in salar type of forest and is used as fodder for buffaloes.

IX– EDIBLE PRODUCTS SPECIES

In view of the growing importance for food it is essential to enlist some of the edible species as listed below which either occur in Rajasthan or which are suitable to be grown in dry or desert areas. It will be in the interest of the State to exploit these species properly.

1. *Anacardium occidentale* Linn. (Cashew). Kernel of fruit is valuable article of commerce.

2. *Calligonum polygonoides* Linn. Common shrub of Bikaner desert. Flowers are edible.

3. *Capparis decidua* (Forsk.) Pax.
4. *Cappasis spinosa* Linn.

Flower buds and fruits of these are used locally in pickles.

5. *Carissa opaca* Stapf. Berries are eaten as tarts, puddings and vegetables.

6. *Cocos coronata* Mart. Fruits edible. Kernels of nuts yield 57-62% of an oil closely resembling coconut oil in taste and colour.

7. *Cordia dichotoma* Forst. Sweetish fruits are edible, raw or stewed or pickled.

8. *Cartaeva religiosa* Forst. Fruits are eaten.

9. *Dactyloctenium aegyptiacum* Beauv. Grass grain edible.

10. *Ehretia laevis* Roxb. Insipid fruits and bark are edible.

11. Emblica officinalis Gaertn. Fruits are edible. Utilization of the produce as assessed in 1964-65 was estimated at Rs, 1,38,913 in Rajasthan.

12. Feronia limonia (Linn.) Swingle. Pulp of fruit is eaten with or without sugar or as chutney.

13. Madhuca indica Gmel. Flowers and fruits edible. Utilization of produce as assessed in 1964-65 was valued at Rs. 18,754 in Rajasthan.

14. Mangifera indica Linn. Fruits are eaten and also the kernels in the form of flour in times of scarcity.

15. Phonix sp. Ripe fruits are eaten raw and terminal buds make excellent vegetable. Sap which is tapped yields toddy and sugar.

16. Salvadora oleoides Dcne. Sweet fruits are edible fresh or dried. Fruits should be taken in small quantities to avoid ulcers in mouth.

17. Salvadora persica Linn. Fruits are edible.

18. Syzygium cumini (Linn.) Skeels. Fruits are eaten and vinegar also is made out of it.

19. Withania coagulans Dun. Fruits are used as a vegetable rennet.

20. Ziziphus mauritiana Lamk. Ripe fruits are eaten and unripe ones are pickled.

21. Ziziphus nummularia W. & A. Ripe fruits are eaten.

X—CONCLUSIONS

The area of Rajasthan is admittedly dry and very hot in summer and is generally poor in vegetation, yet it is not a climatic desert but a biotic one. It will be, therefore, in the interest of the State to exploit the existing minor forest products resources by organizing the extraction departmentally or through a corporation as in Madhya Pradesh. It will certainly be advantageous to grow and maintain the forests and also introduce new species so that the forest department of Rajasthan may obtain the maximum return.

XI—SUMMARY

The existing wealth of forest products in Rajasthan other than timber has been highlighted in this paper. Suggestions have been put forth regarding the proper exploitation of existing species of economic

value as sources of minor forest products. Other species which do not occur in Rajasthan, but can easily be grown in areas of Rajasthan have also been indicated for introduction, in order to add to the resources of Rajasthan. Various items of minor forest products or non-timber products have been dealt within nine groups, viz., gums and resins; tans and dyes, *cutch* and *katha*, seed oils; essential oil-bearing plants, fibres and flosses and material for mats, ropes, huts, brooms and paper, bamboos; bidi leaves, wax, fodder grasses and edible species. The species have been recommended for introduction taking into consideration the site factors.

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SANDBINDERS AND SHELTERBELTS FOR CONTROL OF WIND EROSION

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(With 4 Tables)

I—Introduction

Wind, especially when humidity is low, affects crops adversely by placing them under high transpiration stress. It may also cause scorching of crops, blowing out of newly seeded grainfields, sand blasting, lodging of grain or rubbing and consequent degrading of fruits (Rhee, 1957; Stoeckeler and William, 1949). Wind erosion has become a more serious problem in Rajasthan Canal Command Area where high velocity winds not only increases evapo-transpiration losses but also reduce the capacity of the canals and irrigation channels.

In any wind erosion control programme, apart from the agronomic practices, use of plant communities as sand binders, stabilisation of shifting dunes by afforestation, and spraying and raising windbreaks rank high.

II—Sand Binders

Satyanarayan *et al.* (1966) in their paper on Dune Ecology distinguished five plant communities, viz. (i) *Maytenus emarginata* and *Acacia jacquemontii* community, (ii) *Maytenus emarginata* and *Calligonum polygonoides* community, (iii) *Calligonum polygonoides* and *Balanites aegyptiaca* community, (iv) *Calligonum polygonoides* and *Panicum turgidum* community, and (v) *Calotropis procera* community.

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The common plant species constituting these plant communities are :

1. Trees

Acacia senegal.
Small Trees and Shrubs : *Maytenus emarginata, Acacia jacquemontii, Balanites aegyptiaca, Calligonum polygonoides, Mimosa hamata, Clerodendron phlomoides, Calotropis procera, Lycium barbarum, Sericostema pauciflorum, Aerva persica, Leptadenia pyrokachnica, Tephrosia purpurea, Crotalaria burhia* and *Zizyphus maritiana.*

2. Creepers and Sedges

Citrulus colocynthis, Rhyneosia minima and *Cyperus arenarius.*

3. Grasses

Cenchrus biflorus, C. setigerus, C. ciliaris, Dactyloctenium sindicum, Eragrostis ciliaris. E. tenella, Panicum turgidum, Lasiurus sindicus and *Aristida adscensionis.*

It has been found that shifting dunes compared to stabilized dune have a much better soil moisture status (Krishnan, 1966) and are, therefore, ideal habitat for growing tree and shrub species which not only stabilize these dunes effectively but also provide the much needed fodder and fire wood for the local population. These dunes should, therefore, be stabilized by afforestation and not allowed to become colonized by natural vegetation most of which is composed of species of low economic value. It is with this view that the Central Arid Zone Research Institute, Jodhpur, took up research on development of techniques for stabilization of shifting dunes by afforestation. The details of the technique are discussed below.

III—STABILIZATION OF SHIFTING DUNES

1. Afforestation

The first step in dune fixation operation consist of placing closely spaced vertical brushwood barriers or micro-wind-breaks, starting from the crest to the heel on the windward side of the dune. These barriers may either be erected in 5 m parallel strips or in 5 m² chess board pattern depending upon the wind velocity and wind direction. *Crotalaria*

burhia, Leptadenia pyrotachnica, Zizyphus nummularia, Aerua pseudotomentosa, Calligonum polygonoides, Lasiurus sindicus and *Panicum turgidum* have proved to be economical and useful for erecting such barriers as these are locally available. The fixing of brushwood should be completed before monsoon (Bhimaya, *et al.* 1961).

The stabilization through afforestation may be brought about by sowing of seeds of grasses and creepers and by planting of tree seedlings of suitable species. Sowing of the seeds of grasses and creepers should be carried out just before the onset of the monsoon in between the parallel barriers of brushwood adjacent, but not quite close, to the brushwood strips. Among the grass species, *Lasiurus sindicus, Panicum turgidum, Cenchrus ciliaris, Erianthus munja* and *Cenchrus setigerus*, and among the creepers, *Rhyncosia minima* and *Citrullus colocynthus* have proved to be promising for sowing. A word of caution is, however, necessary here with regard to the selection of shrub and tree species. It should be the aim to restrict the species, as far as possible, to those which meet the twin objective, i.e. leaf forage for livestock and fuel wood for the local populace. This not only helps in stabilising the dune but will also immensely help in augmenting the scarce fodder and fuel resource of the region. Direct sowings of these species have not consistently given good results and hence planting of the seedlings of promising tree species has been preferred as it gave good results. Planting should be deep enough (at least 60 cm below dune surface) so as to lodge the root system in the moist sand pocket. The exact method of planting varies with the different species. For example, branch cuttings of *Tamarix articulara* and *Calligonum polygonoides* gave excellent results, whereas planting of pre-sprouted stumps of *Prosopis juliflora, Albizzia lebbek* and *Dalbergia sissoo* successded well. When potted seedlings are to be planted it is essential to ensure that the coiled up roots are straightened out or cut off before planting or else the coiled roots do not penetrate deep and the trees after a few years growth tend to die. The most successful method of plantation developed at the Institute consists of raising seedlings in "planting bricks". These bricks are prepared with the help of a wooden or a steel mould 30 cm high, 10 cm and 15 cm square at top and bottom respectively (Kaul, 1967). Planting bricks are made out of a mixture of equal proportions of clay, sand and farm yard manure prepared with the requisite amount of water and moulded and sundried with a cavity of 2.5 cm diameter and

15 cm deep at the top to take the seed or stump. During the planting season these bricks, alongwith the seedlings in them, are taken out of the nursery beds, and planted deep (60 cm below the dune surface) at the site with the bricks intact. The planting is carried out at a spacement of 5×5 m. The success of 'planting bricks' depends on the fact that roots are least disturbed during carriage and transplanting, and unless the sand blows away completely from the immediate vicinity of the plants, the roots do not get exposed to hot winds. Besides this, the bricks provide nutrition to the plants in the initial stages and also absorb and retain moisture longer. Recent studies by Kaul and Tyagi (1967) on fertilization of 'planting bricks' have revealed that seedlings of *Acacia tortilis* attained maximum current annual height increment of 2.95 followed by 2.64 m under the treatment combination of 10 gm N+6 gm P and 15 gm N+6 gm P (applied in the form of Ammonium Sulphate and Super Phosphate applied per bricks) respectively.

Afforestation of shifting dunes was carried out in areas receiving 250-425 mm mean annual rainfall. The data on species performance in relation to rainfall is given in Table 1.

Table 1.—Survival rainfall and mean annual height increment (cm) of plant species in shifting dune habitats in relation to rainfall. (After Bhimaya *et al.*, 1963.)

Species	Rainfall Regions					
	200 - 300 mm		300 - 350 mm		400 - 425 mm	
	Survival per cent	Height increment	Survival per cent	Height increment	Survival percent	Height increment
Acacia arabica	*	*	*	*	37	48
Acacia senegal	21	7	*	*	23	24
Ailanthus excelsa	5	21	15	33	74	63
Albizzia lebbek	16	22	33	57	60	79
*Azadirachta indica***	4	46	49	33	50	46
Balanites aegyptiaca	42	4	*	*	*	*
Cordia rothii	77	56	*	*	*	*
Dalbergia sissoo	*	*	52	20	96	50
Prosopis juliflora	30	30	60	44	63	60
Prosopis spicigera	20	12	42	46	85	60
Tamarix articulata	4	15	41	50	50	63
Tecomella undulata	4	11	*	*	7	24
Zizyphus jujuba	14	19	16	21	30	36

* Species not tried.

** Planted on consolidated sandy soil in inter dune area

It is seen that the 13 species planted on shifting dunes under the different rainfall regimes showed a definite increase in their survival and mean annual height increment from one region to another corresponding to the increase in rainfall. Based on the survival and height growth exhibited by the different species, *Balanites aegyptiaca, Cordia rothili, Prosopis juliflora* (only in non-frosty localities) in regions receiving a mean annual rainfall of 200-300 mm and *Ailanthus excelsa, Albizzia lebbek Dalbergia sissoo, Prosopis juliflora, P. cineraria* and *Zizyphus meritina* for regions receiving rainfall of 200-400 mm have been found suitable for planting.

Among the other exotic tree species that were tried, *Acacia tortilis* was found to be extremely promising as a drought-hardy and fast growing species; *Acacia victorae* and *Parkinsonia aculeata* showed great resistance to frost and are, therefore, recommended for localities where incidence of frost is common.

It was observed that the natural vegetation that invades the area following closure intensely competes with the new planted seedlings for moisture and nutrients and, therefore, replacement of casualties either results in failure of seedlings to establish or in their poor growth.

Cost of Afforestation : The itemized cost of afforestation of shifting dunes worked out comes to Rs. 277 per hectare. This includes cost of fencing and mulching materials as well as maintenance during the second and third years.

Table 2—Itemized cost of stabilization of shifting dunes by afforestation

Particulars of work	Cost per 100 ha (Rs)
Cost of *Zizyphus* thorn fencing	7413
Cost of mulching material 1906 head loads	2328
Cost of fixing mulch in 10 ft parallel strips	1250
Cost of seedling production 18000 plants 5×5 meters @ 10 paise per plant	4448
Cost of transplanting—including pitting	7413
Cost of maintenance in the 2nd & 3rd years	4942
Total	27,794
	or Rs. 277 per ha.

If people participation is ensured by the Developmental Agencies, the cost of such afforestation will be negligible.

Future management : The most important task in stabilization of sand dune is the after-management of such afforested dunes. Consideration must be given to long term or permanent closure of such areas, particularly near towns, and the objective should be to eliminate grazing completely. Such rehabilitated dunes within the sound principles of soil conservation can best be managed as cut-fodder and fuel reserve.

2. *Spraying of Sand Dune Stabilization Oil*

This method consists of (1) protection of the sand dunes by fencing to ward off grazing animals, (2) planting of rooted slips of grasses and seedlings, and (3) spraying of the dune surface by an emulsion known as Sand Dune Stabilization Oil (SDS). On an average, the rate of application of SDS oil was about 2110 litres per ha. Only one lance with a 12.5 size nozzle was used for spraying the oil. The windward side of the higher dunes was given a thicker coverage of the SDS oil as these dunes have to face direct impact of high wind velocity (Esso, 1964).

The data on percentage survival of different species recorded at the end of one year in both the treated and the untreated dunes are set out in Table 3.

Table 3—Percentage survival of seedlings after a year of planting on the treated and untreated dunes. (After Esso, 1964.)

Name of species	Percentage survival	
	Treated Dune	Untreated Dune
Acacia tortilis	90 – 95	65 – 70
Eucalyptus hybrid	40 – 45	Nil
Prosopis juliflora	10 – 15	Nil
Saccharum munja	10	Nil
Iolanthus spp.	Nil	Nil

The increased percentage of seedling survival of the different species in the treated dunes can be attributed to non-exposure of the seedling roots and to some extent to better moisture conservation due to the oil mulch.

Table 4—Some of the items of expenditure incurred on sand dune stabilization in the "ESSO METHOD". (After Esso, 1964.)

Particulars of work		Approximate cost for 12 ha (Rs.)
Esso Sand Dune Stabilising oil (10,000 litres) Ex Jaipur		3953 69
Seedlings @ 5 paise per seedling (about 4000 seedlings were planted on treated dunes)		494.21
Labour cost		988.42
Miscellaneous (Transportation of men, material, etc., from Jaipur *to the Site)*		*370.65*
		5806 97
	or	5807.00
Stabilisation cost per ha		*484 00*

The expenditure incurred under this method came to Rs. 484 per hectare, excluding the cost of fencing. Besides being more costly than the brick method, it was observed that the thin crust which is formed as a result of spraying the oil quite often gets cracked due to the abrasive action of the sand-laden winds and thereafter through these cracks the wind caves into the dune surface and thus the beneficial effect of oil mulch is soon nullified.

IV—SHELTERBELTS OR WINDBREAKS

In India, shelterbelt planting programme on an extensive scale was taken up from 1957 to 1959 at the Central Mechanized Farm, Suratgarh, where 102 km long shelterbelts were successfully raised (Bhimaya and Chowdhri, 1961).

In this project three-row shelterbelts were raised on either side of the roads running across the prevailing wind direction. *Dalbergia sissoo* was planted as shade row, whereas *Acacia nilotica* ssp. *indica* and *Zizyphus mauritiana* were grown by seeding in the second and third rows respectively. In case of certain rows only one shelterbelt of three rows was planted on the windward side and on the other side only avenue plantings were carried out in five rows and the species were planted in the ascending order or their height growth, starting from other edge of the boundary with the shrub rows.

1. *Spacing Between and Within Rows*

The three rows in the road side planting were spaced 3m and 2.5m apart, whereas in the case of planting along the out boundary, the first two rows of shrubs were spaced 2.5 m from each other and from the last three rows of the trees which were planted 3 m apart. Thus the total ground width covered by such planting was 5.5 m and 11.0 m respectively. When two belts were planted on either side of the road then 11.0 m wide strip of ground was covered by shelterbelt. Accordingly, for each 1.6 km of shelterbelt planting, an area of land ranging from 0.8 to 1.6 ha was covered by the shelterbelts depending upon whether it was planted on one side or both sides of the road. In the case of the outer boundary about 1 ha per 1 km were covered with shelterbelts. Within the shade row plantings were carried out at a spacement of 3 m, whereas in the second row seedlings were planted at 1.8 m apart. The sowing were carried out by dibbling seeds at a distance of 0.3 m apart.

2. *Soil Working*

Ditches trangular in cross section 45 cm in side and 45 cm in depth were dug along the planting lines with a mechanical ditcher. Pits 30 cm^3 were dug staggered with each other on either side of these ditches for planting seedling. For species which can be seeded, seeding was carried out in the ditch on either side such that the seed sown remains just above the irrigation water level which flows in the ditch. Such ditch side plantings of shelterbelt on an extensive scale proved very successful.

3. *Type of Planting Stock*

Stump planting from one-year-old seedlings of *Dalbergia sissoo* was found to succeed better compared to one-year-old nursery raised seedlings, besides these being costlier to transport and establish. Dibbling of seeds of *Acacia nilotica* ssp. *indica* at a spacement of 30 cm was carried out.

4. *Species Performance*

In all 11 species, viz. *Dalbergia sissoo*, *Eucalyptus* spp., *Syzygium cumini*, *Casuarina equiseetifolia*, *Magnifera indica*, *Grevillia robusta*, *Jaceranda ovalifolia*, *Azadirachta indica*, *Kigelia pinnata*, *Pongamia pinnata* and *Delonix regia* were tried for planting. Of these, *Dalbergia sissoo* has been found

to be the most promising. *Eucalyptus camaldulensis* initially showed promise but was later found to be susceptible to scorching winds. The other species either failed to grow well or did not show the desired form. In the subsidiary rows, *Morus alba, Sesbania aegyptiaca, Leucaena glauca* and *Parkinsonia aculeata* were tried. Of these, *Morus lalba* and *Sesbania aegyptiaca* did well. *Parkinsonia aculeata* performed well but its crown, being feathry, was not found suitable as a shelterbelt species. *Leucaena glauca* did not show much success.

Of the six species, viz. *Acacia nilotica* ssp. *indica, Prosopis cineraria, P. juliflora, Zizyphus nummularia, Z. mauritiana* and *Pithecellobium dulce* which were raised by sowing, *Acacia nilotica* ssp. *indica* and *P. cineraria* did well, whereas the other species were found to be rather slow in establishment. *Prosopis juliflora* failed to establish.

5. *Interculture*

Due to irrigation, rank growth of weeds and grasses that come up adversly compete with the sown and planted seedlings. The common weeds are *Cyperus* spp., *Salsola foetida, Suaeda fruticosa, Haloxylon* spp., *Calotropis procera.* Regular and timely weeding was found to be essential for succesful establishment of shelterbelt.

6. *Replacement of Casualties*

In the failed patches of sown lines very little success was achieved and in such cases it is better to reform the ditches and full scale fresh sowing be carried out, whereas in the case of *Dalbergia sissoo* replacement by stump planting carefully done was successful.

7. *Reduction of Sapping Zone*

The effects of sapping, i.e., the competition of tree roots for moisture and nourishment with the crops adjoining to windbreaks, is very noticeable at the Central Mechanized Farm, Suratgarh. The sapping effect of windbreaks can be effectively reduced by trenching to cut through the roots year after a year (Kelly-Edwards, 1945), or use of a sharp bulldozer—mounted blade to a depth of several feet every few years (Stoeckeler, 1962; Kaul, 1963).

8. *Cost of Raising Shelterbelts*

On an average, cost per kilometre of a three-row shelterbelt on one side and one shade row on the other side of the road works out to Rs. 330/-.

9. *Suggested Plan for Raising Windbreak in the Rajasthan Canal Command Area*

Multiple-row shelterbelts are not only costly to establish but they also cover considerable area of the land which otherwise would go for crop production with medium to small holdings. This obvious loss of land is the main reason why many farmers are reluctant to grow windbreaks. Wind tunnel studies have demonstrated that a narrow shelterbelt may be more effective than a wide one, in width of the zone of the influences (Den Uyl, 1936; Jensen, 1954; Shaple and Lehane, 1955, and Stoeckeler, 1945). Matakin (1934) reported that crop yields are more likely to show a reasonable net gain if narrow windbreaks, occupying as little as two to five per cent of the gross land area, are used. In view of this, for canal command areas, *Acacia tortilis* alternating with *Acacia gregii* within same row is suggested to form a narrow field windbreak. Alternatively, two row field windbreak of either (1) *Erianthus munja* and *Acacia nilotica* ssp. *indica* or *Acacia tortilis*, or (2) *Acacia tortilis* or *Acacia nilotica* ssp. *indica* and *Morus alba* are suggested.

To provide good wind protection to crops, using *Acacia nilotica* ssp. *indica* with a life expectancy of 30 years and an effective height of 5 m reached at age of 15 years, initial plantings should be made in parallel single row lines 100 m apart. Fifteen years later identical plantings can be made 50 m from and parallel to the existing belts. About 15 years thereafter 30-year-old trees in the first set of belts should be cleared out, used for posts, or small wood and replanted with new seedlings placed between the low cut stumps of the recently harvested trees. In low rainfall area, irrigation will be necessary for better establishment of the planted seedlings. Intensive cultivation of the shelterbelts is necessary for its longevity and its effectiveness (Ferber, 1958; Ganguly and Kaul, 1968; George, 1953; Kaul, 1967; Munns and Stoeckeler, 1946, and Read, 1968). This system will provide continuous wind protection on a zone 20 tree height wide. Such field windbreaks occupy a minimum space and provide a very simple scheme of management. They are mostly adapted to irrigated land. Extreme care must be taken to continue

making replants of all felled spaces to avoid gaps in the belt that would reduce its effectiveness as a wind screen. Whereas, for protection of the the canal, a multiple-row-windbreak will be advisable as that will not only provide the desired protection to the canal from sand deposition but will also serve as a source of revenue by way of firewood or timber.

V—SUMMARY

The technique of stabilisation of shifting dunes evolved by the Central Arid Zone Research Institute, Jodhpur, consists of (i) protection of shifting dunes against all biotic interference, (ii) creating micro-windbreaks in the windward side of the dune, either in 5m parallel strips or $5m^2$ chekboard depending upon the wind direction, and (iii) sowing of tree, shrub on the leeward side of the microwind creak and planting of seedlings of tree species. Suitable trees, e.g. *Acacia tortilis*, *Prosopis juli flora* (in frost-free localities only), *Acacia victorae* (for extremely frosty localities), *Prosopis cineraria*, *Zizyphus mauritiana*, *Cordia rothii* and *Calligonam polygonoides* are raised in planting bricks specially designed for the purpose.

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Discussion

J.K. Maheshwari : Have you also conducted studies on the utilization of maritime grasses like *Spartina fownsendit* and *Spinifex squarrosus* as soil binder ?

R N Kaul : I do not think that these species will succeed in the inland sand dunes. We had tried *Spinifex* in the past, and it did not show good performance.

P.C. Nanda : On the leeward side of the micro-windbreak, has any attempt been made to plant *Panicum antidotale* and *Panicum turgidum* which occur naturally in this habitat.

R N. Kaul : Yes, these species were sown and they succeeded. We, however, recommend seeding of *Lasirus sindicus* which is a high yielding forage species.

S.K Jain : Dr. Maheshwari is suggesting *Spartina* and *Spinifex* for sanddunes. These cannot succeed as their water requirements are high.

R.N. Kaul : Yes, I doubt whether these species will succeed under inland dune conditions. As I have said, we have tried *Spinifex* in the past, but it failed to establish.

A.K. Chakravarty : Do you have any information regarding economics of sanddune fixation and shelterbelts planting. If so, what is the cost involved and benefit obtained from such operations ?

R.N. Kaul : Of the different habitats in the arid zone, where afforestation has been carried out, shifting sanddunes due to very conducive soil-water-plant relationship have been found to be ideal habitat for production forestry. The cost benefit ratio works out to 1 : 5. Regarding raising of shelterbelt, this programme can economically and effectively be carried out in regions where irrigation facilities exist, such as the Rajasthan Canal command area.

M N Tewari : To what extent it has been possible to use *Acacia tortilis* as shelterbelts or windbreaks ?

R.N. Kaul : This species has gone into large scale afforestation programme throughout the country. The growth rate and the form of this species show that this will make a very suitable species for planting in shelterbelt programme.

DISTRIBUTION OF ALKALOIDS IN SOME ARID ZONE PLANTS

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(With 6 Tables)

I—Introduction

Many leguminous plants growing abundantly in arid zone area are known by local people for their medicinal values. Keeping this in mind various species, which were known for their medicinal value but were not tested for their alkaloidal content, were tested for the presence of alkaloids qualitatively, in their seeds or various plant parts by some general methods.

II—Materials and Methods

Tests for detection of alkaloids were performed on the seeds of some the following leguminous plants and the results obtained were positive: *1. Abrus precatorius, 2. Prosopis cineraria, 3. P. juliflora, 4. Parkinsonia aculeata, 5. Casia auriculata, 6. C. occidentalis, 7. C. fistula, 8. Albezzia lebbek, 9. Mimosa hamata, 10. Clitoria ternatea, 11. Acacia senegal, 12. A. tartilis, 13. A. nilotica.*

The bark, root, stem and leaves of some leguminous arid zone plants were tested for the alkaloid presence apart from their seeds. These plants were *Abrus precatorius, Prosopis cineraria, Prosopis juliflora, Parkinsonia aculeata* and *Mimosa hamata*. The alkaloids were detected qualitatively by their general precipitating and colour reactions.

General precipitating reagents used for detection of alkaloids include those reagents which when added to solutions of alkaloids give insolube or slightly soluble or amorphous or crystalline precipitates, and with very dilute solutions of alkaloids a turbidity is produced (Cromwell, 1955). To detect alkaloids in solution an extract

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with hydrochloric acid is prepared (Arthur and Cheung, 1960). About 2 gm of chopped material in a specimen tube was covered with 5% hydrochloric acid. Three or four drops of the extract so obtained were taken with 1 drop of alkaloidal reagent. The alkaloidal reagents used were : (1) Mayer's reagent (potassium mercuric iodide), (2) Wagner's reagent (iodine-potassium iodide), (3) Dragendorff's reagent or Kraut's reagent (potassium bismuth iodide), (4) Marme's reagent (potassium cadmium iodide), (5) Hager's reagent (saturated solution of Picric acid in benzene), (6) Sonnenschein's reagent (phosphomolybdic acid), (7) Scheibler's reagent (phosphotungstic acid), (8) Silicotungstic acid reagent and (9) Tannic acid (freshly prepared 5% solution in distilled water).

The reagents were prepared according to Cromwell (1955).

Alkaloids as a group give certain colour reactions, which are used for detection of small quantities of alkaloids. The general colour regents are : (1) Concentrated sulphuric acid, (2) Concentrated nitric acid, (3) Pottassium dichromate solution (5%), and (4) Potassium permanganate solution (5%).

One drop of alkaloid extract prepared is taken on a cavity slide and allowed to evoparate. To the residue of alkaloid so obtained a drop of colour reagent is added and effect observed. The colour reactions are compared with those which are obtained from a sample known to contain definite quantities of alkaloids.

Table 1. Name of the plants of which seeds were examined

Reagent	*Cassia occidentalis*	*Cassia auriculata*	*Cassia fistula*	*Albezzia lebbek*	*Clitorias tesnate*	*Acacia senegal*	*Acacia tortalis*	*Acacia nilotica*
M	xxx	xx	xxx	xxx	xx	xx	xx	xxx
W	xxx	xx	xxx	xxx	xx	xx	xx	xx
D	xxx	xxx	xxxx	xxxx	xxx	xxxx	xxx	xxxx
Cd	xx	x	xx	x	xx	xx	xx	xx
P	xx	x	xx	x	xx	xx	xx	xx
T	xxx	xxx	xxx	xxx	xx	xxx	xxx	xxx
S	x	x	xx	xx	x	xx	xx	xx
W	x	x	xx	x	x	x	xx	xx

III—OBSERVATIONS AND DISCUSSION

The seeds of *Abrus precatorious* were reported to contain indole alkaloids by Henry (1949). Alkaloids' presence was reported in many other species of plants used for these investigations, but not in the plants taken for the present investigation. The presence of alkaloids in seeds of different plants have been recorded in Table 1, and in seeds and different parts of various plants in Tables 2-6. Potassium dichromate solution gives a deep yellow to orange solution with the alkaloid residue and Potassium permangnate solution is decolourised. The strength of precipitates obtained by different reagents, *i.e.* Mayer's reagent (M), Wagner's reagent (W), Dragendorff's reagent (D), Marme's reagent (cd), Hager's reagent (P), Tannic acid (T), Sonnenschein's reagent (S) and Scheipler's reagent (PW) has been judged by eye and observations were recorded thus : xxxx = very strong precipitate; xxx = strong precipitate; xx = moderate precipitate; x = negligible precipitate and — = no precipitate (Arthur, 1962).

Table 2. Detection of alkaloids in Abrus precatorius

Reagent	Part of the plant extract				
	Seed	Bark	Root	Stem	Leaf
M	xxx	xx	xxx	xxx	xxx
W	xxx	xx	xxx	xxx	xxx
D	xxxx	xxx	xxxx	xxxx	xxxx
Cd	xxxx	xxx	xxx	xxx	xxx
P	xxx	xxx	xxx	xxx	xxx
T	xxx	xxx	xxx	xxxx	xxxx
S	xx	xx	xx	xx	xxx
PW	xx	xx	xx	xx	xxx

Table 3. Detection of alkaloids in Prosonis cineraria

Reagent	Parts of the plant				
	Seed	Bark	Root	Stem	Leaf
M	xxxx	xxx	xxx	xxx	xxx
W	xxxx	xxx	xxx	xx	xx
D	xxxx	xxxx	xxxx	xxx	xxx
Cd	xxx	xx	xx		x
P	xxx	xxx	xx	x	x
T	xxxx	xxxx	xxx	xx	xx
S	xx	xxx			xx
PW	xxx	xx			x

Table 4. Detection of alkaloids in Prosopis juliflora

Reagent	Parts of the plant				
	Seed	Bark	Root	Stem	Leaf
M	xxxx	xxxx	xxxx	xxx	xxx
W	xxxx	xxxx	xxxx	xxx	xxxx
D	xxxx	xxxx	xxxx	xxxx	xxxx
Cd	xxx	xxx	xxx	xx	xx
P	xxx	xx	xxx	xx	xx
T	xxxx	xxxx	xxxx	xxx	xxxx
S	xxx	xx	xxx	xxx	xx
PW	xxxx	xxx	xx	xxx	xxx

Table 5. Detection of alkaloids in Parkinsonia aculeata

Reagent	Parts of the plant				
	Seed	Bark	Root	Stem	Leaf
M	xxx	xxx	xxxx	xxx	xxx
W	xxx	xxxx	xxxx	xxxx	xxx
D	xxxx	xxx	xxxx	xxxx	xxxx
Cd	xxx	xxx	xxx	xx	xxx
P	xxx	xxx	xx	x	xx
T	xxxx	xxx	xxxx	xxx	xxxx
S	xx	xxx	xxx	xxx	xx
PW	xxx	xxx	xxx	xxx	xxx

Table 6. Detection of alkaloids in Mimosa hamata

Reagent	Parts of the plant			
	Seed	Root	Stem	Leaf
M	xxx	xx	xxx	xxx
W	xxxx	xxx	xx	xxx
D	xxxx	xxx	xxxx	xxxx
Cd	xx	x	xx	xxx
P	xxx		xxx	xxxx
T	xxx			
S	xxx		xxx	xx
PW	xxx		xxx	xxxx

Errera (1887, 1889) and his school, during their extensive investigations on the distribution of alkaloids, used phosphomolybdic acid, Mayer's reagent, Picric acid, Tannic acid, mercuric chloride and platinic achloride, etc. However, Errera preferred Bouschardt's reagent (I_3-KI solution). Arthur (1961) used Wagner's reagent, Mayer's reagent, Dragendorff's reagent, silicotungstic acid and phosphotungstic acid. Observations made during present investigations indicate that Mayer's reagent, Wagner's reagent, Dragendorff's reagent and tannic acid give strong precicitates and they should be preferred.

IV—SUMMARY

A general survey of the distribution of alkaloids in different parts of the plants growing in arid area of western Rajasthan has been made. The plants studied are *Abrus precatorius*, *Prosopis cineraria*, *P. juliflora*, *Parkinsonia aculeata*, *Cassia occidentalis*, *C. auriculata*, *C. fistula*, *Albezzia lebbek*, *Mimosa hamata*, *Acacia senegal*, *A. nilotica* and *A. tortilis*. Seeds of all the plants examined by the use of eight different precipitating and colouring reagents indicated presence of alkaloids. In *Abrus precatorius*, *Prosopis cineraria*, *Parkinsonia aculeata* and *Prosopis juliflora* alkaloids could be detected in the seeds, bark, root, stem and leaves. Extent of their distribution in relation to their age and the quantity obtained by the precipitating reagent have been presented in Tables 1-6.

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ECOLOGICAL STUDIES ON THE PROSPECTS OF DEVELOPING SOME AGRO-INDUSTRIES IN WESTERN RAJASTHAN

By

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(With 2 Tables)

I—INTRODUCTION

A major part of western Rajasthan is covered with enormous amount of wind blown sand and dunes of various types. The rugged hills of the Aravalli system and the saline areas comprise yet another habitat in the area. In such situations vegetation is of potential importance for its several beneficial influences on the climate and soil and also for its protective and productive functions. Improving the economy of the arid areas would mean settling the nomadic population, providing alternative jobs for agriculturists by developing agro-industries mainly based on the plants and animal husbandry, thereby reducing pressure on the land. A few agro-industries which could possibly be developed in the region are described in these pages. The information is based mainly on the data collected by the authors during their surveys in the region for the past few years.

II—PLANT RESOURCES

The plant resources of western Rajasthan may be broadly classified as *productive* and *protective* plant resources. The productive plant resources may also work as protective elements in the conservation of soil and water resources, but the protective plant resources are mainly the soil binders, wind breaks and shelter belts which have not been dealt with in this note though their importance in imporving

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the socio-economic conditions cannot be underestimated. The productive plant resources have been further classified as follows:

1. Plants used for fibres, mats, baskets and Sirki industry.
2. Plants providing soft wood for matchstick and paperpulp.
3. Plants providing gums, resins.
4. Plants providing dyes and tannins.
5. Plants providing non-edible oils.
6. Plants used as food adjuncts.
7. Medicinal plants.
8. Plants providing fodder for the livestock for milk and meat.

Observations on their distribution and potentialities for exploitation for developing some cottage industries from each group are discussed below.

1. Plants Used for Fibres, Mats, Basket and Sirki Industry

This industry has a very wide scope of development in this tract. Many plants naturally occurring in the area are locally used for the extraction of fibre and manufacture of cordages and ropes. Bast of *Bauhinia racemosa* (Kachnar), *Acacia jacquemontii* (Bawali), *A. nilotica* ssp. *indica* (Kikar) and *A. leucophloea* (Reonja) is used in Pali, Sirohi and Jalore districts for making ropes. Such ropes last for 20-30 days when used constantly for taking out water from the wells for irrigation. Branches of *Leptadenia pyrotechnica* (Khemp) and *Crotalaria burhia* (Sannia) are locally twisted for rough cordage. These two plants are very common in the sandy tract on hummocky terrain where the topography is undulating and on the sand dunes. A few plants not in much use but providing fibre of good quality are : *Sida acuta*, *S. rhombifolia*, *Abutilon indicum*, *A. polyandrum*, *Triumfetta bartramia*, etc. Stem of *Sesbania bispinosa* and *S. sesban*, sometimes weeds, in Bajra and Guar fields, give fibre which may be utilised as a substitute for hemp. Floss from the fruits of *Calotropis procera* is twined locally and used for making cords which are employed for weaving cots. The dried stem of the plant is the common source of wood for making roofs of the huts, locally called 'Jhonpas'. The inflorescence of *Aerva persica* and *A. pseudotomentosa* (Bui, Buida) at maturity gives a floss which is used for stuffing pillows. The stem of *Aeschemone indica*, a plant growing on sandy loam soils, gives a soft wood which is utilised for making hats.

Soft twigs of *Acacia nilotica* ssp. *indica*, *A. jacquemonti*, *Salvadora oleoides*, *Tephrosia falciformis* are used for making baskets. Twigs of *Alhagi-pseud-alhagi* (Jawasa) are also used for making baskets. *Imperata arundinacea*, *Vetiveria zizanoides* and *Typha*, all from aquatic habitats on the bunds of the canal sites, tanks and water reservoirs, are used for making sirkis, fans and mats. *Vitex negundo* (Samla), a plant found on the riverbed terraces, gives excellent and durable baskets. So also *Tamarix aphylla* (Jhau) and *T. diocia*, occuring on the islets of river Jawai and Luni. Branches of the local grasses and other plants are used for making brooms which are sometimes sold in the market. Among the grasses *Aristida setacea*, *A. adscensionis* and *Eremopogon foveolatus* are the common species used locally along with branches of *Tamarix*, *Crotalaria* and many other plants.

The ecological characters of these species are described in Table 1 showing their habit, habitat, associates, crown cover, density and frequency as recorded during various surveys. This gives an idea about the ecological amplitude of the species which may be useful while selecting the species for introduction in similar enviornment. Besides the indigenous species, some exotics may also be tried in order to improve the existing resources which are discussed separately.

2. Plants providing Soft Wood for Matchstick, Sports Goods and Paper Pulp

The importance of soft wood in various industries need not be stressed. *Ailanthes excelsa* (Arua), growing to the height of a tree, is cultivated around the irrigated areas and on field boundaries on sandy loam to sandy clay loam soils in Jalore, Pali and Jodhpur. The wood is suitable for making newsprint and for matchsticks. *Dalbergia sissoo* (Shisham), a plant of fairly deep claysandy loam soil, provides pulp for paper. Other plant species which may be used are *Moringa oleifera* which grows well on the field boundaries. *Ricinus communis* (Arand), which may be cultivated on sandy loam to sandy clay loam soils with or without irrigation, would provide pulp for writing and printing board from the stocks. The wood of *Moringa* is of special value for making shuttles and picking sticks which are used in textile industry.

Several grasses like *Heteropogon contortus* (Siyan, Surwal), *Saccharum spontaneum* (Kans), *S. munja* (Munj) are useful for paper pulp manufacture. There are vast areas of wastelands where these grasses may be encouraged by protection from grazing. '*Birs*' in districts Pali, Jalore and

Table 1. Ecological features of some fibre yielding plants used in western Rajasthan

Plant	Habit	Habitats	Chief Associates	Density of plants/hect.	Type of vegetation	Crown cover	Ht. in m.
1. *Bauhinia racemosa*	Tree	Alluvial plain	Cultivated	4-6	-	9-25	6-12
2. *Acacia nilotica* ssp. *indica*	Tree	Alluvial plain	*A. indica, P. cineraria A. cupressiformis*	5-30	Ravine forest	16-36	8-16
3. *Acacia jacquemontii*	Shrub	Sand dune	*C burhia, A. persica, L. pyrotechnica Z. nummularia*	40-100	Sand dune scrub	4-9	2-3.5
4. *Acacia leucophloea*	Tree	Older alluvium semi-rocky areas	*S. oleoides, P. cineraria, Z. nummularia, E. caducifolia*	20-30	Xeromorophic woodland	16-36	8-14
5. *Leptadenia pyrotechnica*	Under-shrub	Sand dune and hummocky alluvial plains	*A. persica, A. jacquemontii, C. burhia*	60-200	Sand dune scrub	0.5-1 0	0 5-1.5
6. *Crotalaria burhia*	Under-shrub	Sand dune and hummocky alluvial plains	*L. pyrotechnica, A. persica, A. jacquemontii*	200-2000	Sand dune scrub	0.3-0.8	0 5-0 8
7. *Calotropis procera*	Shrub	Older alluvial plains	*A. jacquemontii, A. persica, L. pyrotechnica*	50-200	Sand dune scrub	0.5-1.0	1.0-3.0
8. *Aerua pseudo-tomentosa*	Under-shrub	Older alluvial plains	*A. jacquemontii, A. persica, L. pyrotechnica*	4000-2000	Sand dune scrub	0.4-0.9	0.4-0.8
9. *Aerua persica*	Under-shrub	Older alluvial plains	*A. jacquemontii, A. persica, L. pyrotechnica*	—	—	—	—
10. *Aschynomene indica*	—	Ponds and canal banks etc.	—	—	Aquatic	—	—
11. *Imperata arundinacea*	Grass	Ponds and canal banks etc.	—	—	Aquatic	—	—

true gum arabic. Gum from *Prosopis juliflora* trees has recently been exploited in some areas and is a good source of revenue to the forest department.

Commiphora wightii (Gugal), a plant of the rocky and semi-rocky sites and piedmont slopes, gives Indian bdleium, which is obtained by the incision of the bark. Since the method of tapping followed locally is crude and unscientific the yield is low and the gum obtained is of poor quality which often results in the death of the tapped trees.

Butea monosperma (Palas), though not a very common plant in this region, occurs only on the foothills of the Aravallis on medium heavy soils having good drainage and has a limited scope of exploitation in the region. The plant yields gum which is sold in the market as '*Kamarkas*' and the plant is a host for lac insects.

Table 2 gives the ecological features of the gummiferous plants of western Rajasthan.

4. *Plants Providing Dye and Tannins*

With the introduction of synthetic dyes the use of plant part as dyeing material is not much in vogue. Some of the plant dyes are still in use in this region, eg. turmeric is widely used for dyeing clothes. Plant dye industry may prove to be of local importance. Some of the plants which yield dye are *Butea monosperma* (yellow dye from flowers), *Arnebia hispidisma* (yellow dye from roots), *Rumex dentatus*, *Morinda tinctoria* (yellow dye from roots), *Wrightia tinctoria* (blue dye from flowers). *Indigofera tinctoria* (neel) has a wide distribution in the area. *Lawsonia indica* (Mehandi) is widely cultivated near Sojat and is a very good industry.

Plant like *Cassia auriculata* (Anwal), *Accacia leucophloea* (Reonja), *A. nilotica* ssp. *indica* (Babul), *A. iacquemontii*, *Dichrostachys cinerea*, *Rhus mysorensis*, *Zizyphus mauritiana* (Bordi) *Z. nummularia*, *Tamarix troupii* and *T. aphylla* are the local plants available as source of tanning material and are used extensively.

5. *Plants Providing Non-edible Oils*

During recent years non-edible oil industry has seen much development as a regular trade commodity. The main difficulty experienced in the development of the industry is the uneconomic collection of

Table 1 Concluded

Plant	Habit	Habitats	Chief Associates	Density of plants/hect	Type of vegetation	Crown Cover	Ht in m
12. *Vetiveria zizanoides*	Grass	Ponds and canal banks etc.	—	—	Aquatic	—	—
13. *Typha* sp.	—	Ponds and canal banks etc.	—	—	Aquatic	—	—
14. *Vitex negundo*	Shrub	Younger alluvium	*A. jacquemontii, A. nilotica, A. indica*	20-25	Ravine forest	5-9	2-13
12. *Tamarix dioica*	Shrub	Younger alluvium	*C burhia, L. pyrotechnica, C. procera*	200-5000	Ravine forest	0.5-2.0	0.7-1.5
16. *Tamarix aphylla*	Shrub	Younger alluvium	*C burhia, L. pyrotechnica, C. procera*	100-500	Ravine forest	0.5-2.0	0.7-1.5
17. *Aristida setacea*	Herb	Older alluvium	*C. ciliaris, C. biflorus, A adscendens, C. jawarancusa*	500-2000	*Cenchrus* or *Aristida* type	0.1-0 4	0.4-0.6
18. *Aristida adscensionis*	Herb	Older alluvium	*A. funiculata, C. ciliaris, C. setigerus*	1000-5000	*Aristida* type	0 1 0.5	0.5-0.75
19. *Eremopogon foveolatus*	Herb	Older alluvium	*D. annulatum, C. jawarancusa C. ciliaris, C. setigerus*, etc.	500-2000	*Dichanthium* or *Schima* or *Cenchrus* type	0.5-0.7	0.6-1.0

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Table 2. Ecological features of some gum yielding plants in western Rajasthan

Plant	Habit	Habitat	Vegetation Type	Chief Associates	Ht. range in m.	Crown cover in s m.	Density/ hect.
1. *Acacia senegal*	Tree	Hills, upper piedmont and stabilised dunes	Xeromorphic thorn forest	*Maytenus emarginata, Anogeissitaus pendula, Moringa coccanensis, E caducifolia, Commiphora wightii*	10-12	20-64	15-25
2. *Acacia leucophloea*	Tree	Piedmont (upper and lower), gravelly rocky plains	Xeromorphic thorn forest and woodland	*P. cineraria, C. decidua, S oleoides, E. caducifolia, Z nummularia*	8-12	75-56	20-30
3. *Acacia nilotica* ssp. *indica* (= *Acacia arabica*)	Tree	Younger alluvium	Ravine forest	*A nilotica* ssp *cupressiformis, Azadirachta indica, P. cineraria, Tamarindus indica*	10-15	16-36	5-30
4. *Commiphora wightii*	Tree	Hill and rocky surface	Xeromorphic thorn forest	*A senegal, M emarginata, A. pendula, Z. nummularia*	1-3	4-65	5-10
5. *Butea monosperma*	Tree	Foot hills (above 500 mm rainfall)	Dry deciduous	*A. senegal, A. pendula, E caducifolia, A leucophloea*	8-12	16-36	20-50
6. *Prosopis juliflora*	Tree/ shrub	Roadside plantation and waste places	Wood land	*P. cineraria, A. leucophloea, Azadirachta indica, Albizzia lebbek*	3-6	16-36	30-100

seeds and their standardisation. *Salvadora oleoides* and *S. persica* are the potential source in western Rajasthan (Gupta and Saxena, 1966) as shown by their distribution based on air-photo studies. Other sources which may be worthy of tapping are the seeds of *Citrullus colocynthis* (tastumba) *C. lanatus* (Matira), *Azadirachta indica* (Neem) and *Pongamia pinnata*. Cultivation of *Ricinus communis* has a very wide scope as a cash crop. Matira has a wast potential for edible oils, and scientific cultivation of this plant is very desirable over large areas in view of oil scarcity in the country.

6. *Plants Used as Food Adjuncts*

Many plants in the region are used as food either as delicacies or during the famine and scarcity periods. Some of these are regularly used for increasing the bulk of the cereals without any ill effects on the health. These have been described separately in detail (Gupta and Kanodia, 1967; Gupta, 1967; Kanodia and Gupta, 1968). The potential ones with higher nutritive value may be looked upon as a good source for relieving pressure on the cultivated and conventional foods.

7. *Medicinal Plants*

In most cases our knowledge of the medicinal plants used depend upon the local uses to which the plants are employed (Gupta *et al.*, 1966) and much remains to be done regarding their active principle, chemical composition and alkaloid contents. It may be pointed out that the abundance of a medicinal plant in its wild state may not be a source of wealth and much depends upon its marketability, which is conditioned by economic factors, improvement of yields, primary processing and with due provision for the preservation of the species against over-grazing and destructive collection methods. Since it has been recorded that a fairly wide range of xerophilous plants are now raised in quantity in regions of much lower aridity, with markedly higher yield, tests could be made to indicate the likelihood of the same crops paying in arid zone, using similarly selected strains or ecotypes. Recent trials with some plants like *Plantago ovata* and *Anethum sowa* are quite encouraging.

Some of the plants *Sarcostemma acidum* (Khurasani tanta), *Azadirachta indica*, etc. are used as insecticides but on a limited scale. Decoction from the plants of *Sarcostemma acidum* and *Nerium indicum* is sometimes

used to destroy white ants and bugs while the leaves of *Azadirachta indica* are placed in boxes to repel insects and preserve wollens. The bulb of *Urginea indica* (Jangli-Kanda) is a source for raticide. *Tephrosia purpurea* is the common source of rotenone having insecticical properties.

8. *Plants Providing Fodder to Livestock for Milk and Meat*

Animal husbandry is the main subsidiary activity in this tract and much is needed to put this industry on a firm footing. Due to high animal population, and unmanaged and uncontrolled grazing, the natural pastures are very much degraded. This has resulted in the growth of unpalatable, less nutritive and regressive annual species like *Aristida* sp., *Melanocenchris jacquemontii* and *Tephrosia purpurea* at the expense of palatable, more nutritive, perennial species like *Cenchrus ciliaris, C. setigerus, Lasiurus sindicus, Dichanthium annulatum*, etc. It is, therefore, imperative that proper range management practices should be adopted in order to improve the existing pastures, thus increasing the animal productivity. Ecological studies on these resources have been made by different authors. Since these are described elsewhere in detail (Gupta, 1971; Gupta and Sharma, 1971) the space does not permit to do full justice to the problem.

III—IMPROVEMENT OF PLANT RESOURCES

The plant resources in the region may be improved firstly by planting suitable species of economic importance from the analogous climatic regions, and secondly by improving the stock of the existing species by various biological means. Conservation of the existing plant resources from over-exploitation by suitable management practices is of considerable significance in the arid regions.

For selecting plants from the analogous climatic regions a thorough understanding of the ecological, physiological and genetic basis of the drought resistance is necessary. Significant success may be achieved by introducing plants from similar climatic conditions but it would require detailed study of the individual species in its homeland and its adaptability to the local conditions. Great difficulty is experienced in view of the incomplete floras giving information on the biology of the plant species. Recently attempts to acclimatise and cultivate the exotics like *Agave, Eucalyptus, Acacia* and *Commiphoras* in the arid regions have

been partially successful. Existing plant resources may be improved firstly-by conserving them by protection from overgrazing, cutting and lopping, etc. and by improving the strains of the exisiting varieties through genetic means. For such studies the autecological studies play a vital role in understanding the ecological amplitude, moisture requirements, flowering and fruiting behaviour and finally the chemical composition, active principle and alkaloid contents of the plant species to be introduced.

IV—SUMMARY

Major part of western Rajasthan is covered with enormous amount of wind blown sand and dunes of various types. The rugged hills of the Aravalli system and the saline areas provide other habitats. The vegetation on such habitats is of potential importance for its protective and productive functions since a large proportion of the population is engaged in agriculture. A permanent approach for soil conservation in the tract and improvement of the economic condition of the population lies in successful introduction of economically important plants so that some agro-industries in the region may be developed. Ecological surveys in the region have revealed that there are certain plants available in the region which are used for various industries like fibre, basket, soft wood, gums and resins, dyes, tannin, medicine and forage. Ecological attributes of such plants on different land forms are described along with the suggestions for their improvement.

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A.K. Chakravarty : The author enumerated various species of plants which are used in cottage industries etc Is there any information about marketing, cost of production, internal or external trade, etc. with regard to the plant material used for industries ?

R.K. Gupta : The suggestion is worth consideration and some work may be taken up by economists or some other agency in this direction.

HYDRO-PHYSIOLOGICAL INVESTIGATIONS ON IMBIBITION AND GERMINATION OF SEEDS OF *PROSOPIS CINERARIA* LINN. MANTISQ.

By

KAMAL MOHNOT

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(With 4 Tables)

I—INTRODUCTION

Despite a great surge of interest in the physiology of seed germination in recent years, many gaps still exist in our knowledge and understanding of the mechanisms that regulate germination of seeds of plants inhabiting arid regions (Mayer and Mayber, 1963). It is more so with the plants of Rajasthan desert, as comparatively few studies have been made so far as germination of seeds of the plants of this region is concerned. Inspite of the fact that germination does not present much of a problem with the seeds of most of crops grown in this State (Singh, 1968), seeds of a large number of arid zone plants of much economic value indicate severe reluctance to germination. Moreover, problems in seed physiology that seem simple and settled by experiments carried out in the past would possibly need a thorough reworking and revaluation by a suitable combination of appropriate physiological methods and new biochemical techniques that are now being increasingly developed (Crocker and Barton, 1957).

The investigation reported in this paper forms only a part of a larger scheme of research on germination of seeds of arid zone plants. It was planned to furnish the information regarding hydro-physiological relations of seeds of *Prosopis cineraria* pertaining to imbibition and germination.

Prosopis cineraria, commonly known as *Khejadi*, is one of those few typical desert inhabiting plant species, which exhibits excellent survival potentiality in dry and barren areas of Rajasthan desert. In the extreme heat of arid summers when other plants are rarely visible over vast areas, this tree apparently withstands destructive effects of prevailing high temperature and drought because of persistant scarcity of water.

Probably it surpasses almost all other trees of this desert in its capacity to tolerate different climatic hazards and to survive well even under hostile conditions.

Prosopis cineraria is a moderate sized thorny tree. It had been recommended as a sand binder for arid areas. It yields a very hard wood which makes excellent fuel and charcoal. The pods and leaves are used as fodder (Badhwar, Dey and Griffith, 1946). Its unripened green fruits are locally used as vegetable and are known by the name of 'Sangrian', which together with the seeds of *Acacia senegal* known as 'Kumatia' and green fruits of *Capparis decidua* known as *Kerr*, make a local vegetable dish 'Pachkuta'.

II—MATERIAL AND METHODS

Prosopis cineraria flowers in November. The fruiting starts from the month of March and continues till June. Naturally mature seeds could mostly be collected during May and June. The seeds experimented with were collected in the year 1963. The seeds were separated from pods, and then cleaned and stored in glass bottles.

There were 10 to 15 seeds in each pod. The seeds are sub-convex, slightly unequal at hilum with a peak-like small conical projection towards the hilum with a big centrally placed areole 3.5×3.8 mm. The seeds are 5 to 7 mm. long, 3 to 4 mm. wide and 1.7 to 3 mm. thick.

Imbibition studies were initially made by noting the differences in weight and volume of imbibed seeds as compared to those of the intact seeds, and then in subsequent experiments only by observations made by the nacked eye. All the experiments pertaining to imbibition or germination were carried out in aseptic laboratory conditions of light and temperature with sterilized seeds and in sterilized petri dishes in the usual manner.

Seeds were considered to have germinated when the emerging radicle was easily visible. The dishes were examined at intervals of 18 to 24 hours. In general, three replicates of 50 seeds each were used for each experiment.

Imbibition and germination studies were made in order to note the effect of different levels of moisture (i) by placing the seeds directly on moist filter paper in petri dishes, (ii) by keeping the seeds under water, and (iii) by transferring the water-imbibed seeds to petri dishes,

i.e., by placing them first under water and thereafter transferring them to petri dishes. The results were recorded separately.

The green, half mature and mature seeds having different moisture content were taken in order to study the relation of the moisture content of seeds to the permeability of the seed coat and germination of the seeds.

Moisture contents of the seeds were determined in the following way :

First of all the fresh seeds having different moisture content were weighed accurately and separately in each case in a crucible of known weight. They were then placed in a hot air oven at 60°C for 24 hours and then at 80°C to 90°C for 24 hours. Crucibles containing seeds were then taken out from the oven and kept in a desiccator and dry weight was noted. This process of drying and desiccating was repeated till constant weight was obtained. By substracting final weight from original weight, the moisture content was determined.

III—RESULTS AND DISCUSSION

As in the cases of most other leguminous seeds, these seeds are characterised by hard impermeable seed-coat which is one of the main causes of failure of germination. That is why the study relating to moisture content assumes importance and appears to be essential. Such investigation might throw light on the problems as to when, in the course of maturation, the seed coat would become impermeable. The moisture content directly influences viability, maturity and permeability of seeds and, in turn, the processes of imbibition and germination.

The increase in weight and volume of seeds due to imbibition has been indicated in Table I.

Table I. Increase in weight and volume due to imbibition of water by the seeds of Prosopis cineraria

	Number of seeds	Original weight/volume of seeds	Weight/volume of imbibed seeds	Weight/Volume of water imbibed
Weight in gm	100	4.9680	13.5200	8.5520
Volume in ml	100	4.00	10.00	6.00

It can be calculated by analysing the data presented in Table 1 that a single seed of average 49 mg. in weight requires 85 mg. of water by weight and 6 ml. by volume, for imbibition and early germination. If the size of the seed is considered by its length and if it is correlated with the amount of water which is needed for imbibition and germination, an interesting relationship emerges. The length of the seed happens to be 5 to 7 mm and the water requirement for its germination is 6 ml.; it would mean that about 1 mm. of the seed length would require 1 ml. of water to be absorbed for its germination, Baxi (1965) reported that the seeds of *Indigofera cordifolia* were found to germinate even if a single seed was able to get less than one milligram of water at the time of germination provided that other conditions were favourable. The average seed weight of *Indigofera cordifolia* seeds is also much less than one mg. each. In the present case, of the seeds of *Prosopis cineraria*, the average weight of a single seed is 49 mgs. and the water requirement by weight is less than double of the original seed weight. So it would almost be equal in both cases if the ratio of the water requirement by weight and the original seed weight is taken into consideration. This comparision is interesting when it is correlated with the above observation that the water requirement could be considered as related to the seed length. The requirement of water for imbibition of seeds could thus be considered as bearing a definite relation to the size and weight of the seed.

The moisture content of fresh seeds was found to be 14.40 percent at the time of their collection. But a steady decrease in moisture contents was observed with the increase in storage period. The results have been incorporated in Table 2.

Table 2. Seeds of Prosopis cineraria showing steady decrease in moisture contents with the increase of storage period

Storage Period	Percentage moisture content
0 months	14 40
4 months	9.70
12 months	7.78

The reduction of moisture content might possibly help in preserving the viability of the seeds for a longer time. This probably affords a clue to the problem as to why seeds of desert plants have been found to remain viable for longer periods.

The relation of the moisture content of the seeds to the permeability of the seedcoat and germination of seeds was studied in respect of green, half mature and mature seeds, having different moisture levels. It was observed that the permeability decreased with decrease of moisture content. The data have been presented in Table 3.

Table 3. Relation of moisture content to the imbibition and germination of seeds of Prosopis cineraria

Moisture percentage	Seeds directly placed in petridishes			Seeds first soaked in water and then placed in petridishes		
	Imbibition percentage	Germination percentage	Germination percentage on removal of seed-coat	Imbibition percentage	Germination percentage	Germination percentage on removal of seed-coat
66.35	100	4	40	100	5	15
38.55	100	80	80	100	85	85
14 40	60	23	25	63	25	26
9.70	20	20	20	20	20	20
7.78	13	12	13	18	17	17

At the moisture level of 66.35% the seeds indicated 100% permeability to water, but only 4% seeds were found to germinate; but after removal of the seed coat, germination increased to 40% in case of seeds kept directly in petridishes. At the same time 5% germination was found in seeds which were presoaked in water for imbibition for 24 hours and then placed in petri dishes for germination; germination, however, increased to 15% if the seed coats were removed. It would tend to indicate that seeds were injured by excess of water soaking. The moisture level of the seeds at 38.55% also indicated 100% permeability to water, but germination unexpectedly increased to as high as 80%. The removal of seed-coat did not bring about any increase in germination. With seeds at 14.40% moisture level, permeability to water was only 60% and germination was found to be 23% which increased by only 2% with the removal of the seed coats. With seeds at 9.70 and 7.78% moisture levels respectively, only 20 and 13% seeds were found to be permeable to water and remaining 80 to 87% seeds were characterised by different permeability, i.e., they became permeable irregularly and at different times. Almost all the imbibed seeds germinated.

Information so far obtained by other workers regarding the relation of moisture content of developing seeds to their impermeability and germination consisted largely of isolated facts. In this respect the reports of Helgeson (1932); Hutton and Porter (1937); Brown and Porter (1942); Raleigh (1943), Porter (1949) and Kamal Mohnot (1965 and 1966) are of considerable importance.

Table 4. Imbibition and Germination of seeds of Prosopis cineraria at different levels of water

Levels of water	Imbibition percentage	*Absolute germination percentage	**Correlative germination percentage
Under water	12	11	92
In petridish	12	11	92
First under water and then in petridish	18	17	94

*The term 'Absolute germination percentage' has been used to indicate the relation of germinating seeds to the initial number of seeds, i e, the percentage as calculated on the basis of the original number of seeds taken

**The term 'Correlative germination percentage' has been used to indicate the correlation of the germinating seeds to the number of imbibed seeds, i e., the percentage of germination as calculated on the basis of the number of imbibed seeds

Table 4 indicates that germination percentage was comparatively higher in case of seeds first kept in water for soaking and then transferred to petridishes for germination than in the case of seeds which were either kept in water for germination or which were kept on petridishes without being first kept in water. Though the overall absolute germination percentage attained by any of these methods in laboratory conditions was not high, correlative germination percentage was quite significant in each case, attaining a value of as much as 92 to 94%, meaning thereby that the embryo of the seed was not dormant. The observations reported by Morinaga (1926) on these lines are significant in this connection.

IV—Acknowledgements

The author is indebted to Dr. U.N. Chatterji, formerly Professor of Botany, University of Jodhpur, and to Dr. D.N. Sen of the Department of Botany, University of Jodhpur for their keen interest and helpful suggestions.

V—SUMMARY

Prosopis cineraria, commonly known as *Khejadi*, is one of those few typical desert inhabiting species, which exhibits excellent survival in dry and barren areas of Rajasthan desert.

The relation of the moisture content of the seeds of *P. cineraria* to the permeability of the seed coat and germination of the seeds was studied in respect of green, half mature, and mature seeds having different moisture levels. It was observed that the permeability decreased with the decrease of moisture content. A hundred percent permeability was observed at 66.35 and 38.55% moisture level. Germination was observed to be only 4% and 80% respectively. Removal of seed coat enhanced germination to 40% in the former case, but was not improved in the latter case. In the mature seeds having 14.40% 9.70% and 7.78% moisture level imbibition was observed to be 60,20 and 13% respectively. Germination was observed to be 23% in the case of seeds having 14.40% moisture level, but in the two other cases, nearly all imbibed seeds germinated.

Imbibition and germination of seeds kept under these conditions, viz., (i) in water (ii) on moistened filter paper in petridishes, and (iii) initially in water and thereafter transferred to petridishes, showed that the third method was comparatively better than the others.

STUDIES ON GERMINATION OF SEEDS OF *ABRUS PRECATORIUS*

By

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ABSTRACT

Investigations were undertaken with a view to study the germination behaviour of the seeds of *Abrus precatorius*. The seeds as such were found to be incapable of germination and they were exposed to various physical and chemical treatments to enhance their permeability and germination.

Chilling the seeds did not bring about any imbibition or germination. Treatment with hot water rendered the seed coats permeable so that imbibition took place to the extent of 85 to 90% but the percentage of germination was low. Seeds exposed to dry heat, although imbibed, were not observed to germinate.

Seeds treated with 10% potassium nitrate indicated a somewhat increased imbibition and germination. Those treated with ethyl alcohol yielded germination values of 85 to 90% similar to those treated with acetone and chloroform. Treatment with sulphuric acid was found to be successful in inducing 90 to 95% germination.

Exposure of the seeds to different temperatures in continuous light or continuous dark was not found to have any appreciable effect on germination.

Treatment with 250 ppm solutions of glucose and tryptohan did not alter the rate or the percentage of germination. Seeds were also treated with different concentrations of sodium dimethyl diethyl carbonate and orthofluorophenoxy alpha methyl acetic acid change in percentage of germination.

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CHANGES IN LEVELS OF PHOSPHORUS DURING GERMINATION OF SEEDS OF *PHASEOLUS RADIATUS* LINN. AS AFFECTED BY ORTHO-FLURO-PHENOXY-ALPHA-METHYL ACETIC ACID

by

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(With 6 Tables)

I—Introduction

Phosphates play an extremely important role in a variety of reactions during the germination of seeds. Thus phosphates would be required for the formation of nucleic acids which in their turn would be directly linked with protein synthesis and the hereditary constituents of the plant cells. In the seeds of many species of plants phosphorus appears to be present in appreciable amounts. Of the total amount of phosphorus, most of it would be present as Mg, Mn or Ca salts of inositol hexaphosphoric acid, i.e. phytin, which might be of variable composition. Ashton and Williams (1958) have reported that wheat phytin contained 12% Ca and 1.5% Mg, while oat Phytin contained 8.3% Ca, 15% Mg. and 5.7% Mn. Phytin generally constitutes 80% of the total phosphorus of plant seeds, the remaining 20% is found in the form of the organic compounds like nucleotides nucleic acids phospholipids, phosphorylated sugars and phosphoproteins. As a general rule, inorganic phosphates appear to be stored in very small amounts. So it should be deemed essential that phytin must be broken down to provide inorganic phosphorus to be utilised in the respiratory process. Albaum and Umbreit (1943), Ergle and Guinn (1959), Mayer (1958) and Pears (1953) have reported that during the germination of seeds in the case of oats, cotton and wheat respectively, an enzyme phytase appeared which hydrolysed phytin. This enzyme was stable at temperatures upto 50°C and its optimum pH was about 5.4. Pears (1953) has reported that phytase was present in the endosperm of wheat. Kathju and Tewari (1968) have noticed the acid phosphatase activity in the nucleus of the radicle cells of *Vigna sinensis*. Thus the changes in the level of the organic phosphorus were considered to be very important to be studied.

In the seeds of *Phaseolus radiatus* the changes in the level of the organic and inorganic phosphorus have been studied during germination as affected by different conditions. The changes in the level of phosphorus were also studied in the seeds soaked in different concentrations of ortho-fluoro-phenoxy methyl acetic acid for six hours and germinated as usual. This chemical has been listed as a growth inhibitor by Tewari (1968).

II—Materials and Methods

The seeds of *Phaseolus radiatus* were germinated in petridishes lined with filter paper as usual. Phosphorus was estimated colorimetrically by the method of Fiske and Subbarow (1925). For the determination of the phosphorus, 1 gm of the seeds was homogenized in 10 ml of 10% trichloroacetic acid to obtain a 10% homogenate. The homogenate thus obtained was centrifuged in an international refrigerated centrifuge for 10 minutes at 1000 RPM at 0°C. The inorganic and the organic phosphorus were estimated in the supernatent thus obtained. The phosphorus levels were also studied in the seeds germinated in light and dark.

For the determination of phosphorus in 1.0 ml of the 10% TCA supernatent, 1.0 ml of 5 N sulphuric acid and 1 ml of 2.5% ammonium molybdate and 0.1 ml of the reducing reagent were added. The volume was made upto 10 ml and the colour intensity was measured after 10 minutes using red filter.

For the determination of the total phosphorus (organic as well as inorganic) in 0.5 ml of the supernatent liquid 0.4 ml of 10 N sulphuric acid was added, and the colorimeter tubes were kept in an oven at a temperature of 140°C for one hour and then 1 ml of H_2O_2 (100 vol.) was added. The tubes were again kept back in the oven. When the contents of the tube became colourless and when the original volume, i.e. 0.5 ml was restored, 1.0 ml of distilled water was added. The tubes were then placed in an electric water bath for 30 minutes to bring about the degradation of the pyrophosphates.

The tubes were taken out and reducing reagent was added and the colour intensity was measured as usual. The amount of inorganic phosphate was subtracted from the total phosphorus value so as to deduce the amount of organic phosphorus.

III—RESULTS AND DISCUSSION

The amounts of organic, inorganic and total phosphorus have been tabulated in Table 1. It is evident that the percentage of organic phosphorus was near about double that of inorganic phosphorus in the air dry seeds of *P. radiatus*.

Table 1.—The amount of total, organic and inorganic phosphorus in the seeds of Phaesolus radiatus

S No.	Types of phosphorus	Percentage
1.	Inorganic	0.699
2.	Organic	1.311
3.	Total	1.91

The changes in the levels of organic and inorganic phosphorus were also studied during the germination of the seeds. Estimation was carried out after every 12 hours of germination. The changes in the level of organic and inorganic phosphorus have been tabulated in Table 2.

Table 2.—The changes in the organic and inorganic phosphorus

Time in hours	Inorganic phosphorus (percentage)	Organic phosphorus (percentage)
0	0.69	0.31
12	0.21	1.71
24	0.10	2.09
36	0.15	1.63
48	0.17	1.42

From the data presented in Table 2 it would be quite obvious that the level of the inorganic phosphate decreased rapidly in all the seeds during germination. After 12 hours the level of the inorganic phosphorus was found to be three times less per gram of seed material than what it was at zero hour. In next 12 hours the percentage of phosphorus was reduced to half of its former level, but after 36 hours the level again started increasing and this increase was maintained even after 48 hours.

The levels of organic phosphorus were also studied during germination. The levels of organic phosphorus was quite high in air day seeds but even then it went on increasing in the first 24 hours of germination. In first 12 hours the level of the organic phosphorus was 1.3 times higher than its level at zero hour and in 24 hours its level was 1.7 times higher than what it was at the zero hour. But after 36 hours of germination the level of the organic phosphorus started decreasing, and after 48 hours its recorded level was only 1.4 times higher than what it was originally in air dry seeds. From the data presented above it would be apparent that during the process of germination, in the first 24 hours, the inorganic phosphorus was converted to organic phosphorus, but after 36 hours such a conversion appeared to be reversed.

The effect of temperature was also studied on the levels of inorganic and organic phosphorus. The results have been tabulated in Tabels 3 and 4.

Table 3.—Changes in the levels of inorganic phosphorus during germination in relation to temperature

Temperature in °C	Concentration of inorganic phosphorus in mg/gm				
	Time in hours				
	0	12	24	36	48
0	0 697	0 635	0 685	0 685	0 686
20	0 697	0.273	0 134	0 143	0 165
25	0 697	0 253	0 128	0 149	0 153
30	0 697	0.229	0 121	0 150	0.167
35	0 697	0 216	0 103	0 151	0 172
40	0.697	0 263	0.128	0.149	0.168

Table 4.—Changes in the levels of organic phosphorus during germination in relation to temperature

Temperature in °C	Concentration of phosphorus in mg/gm treatment				
	Time in hours				
	0	12	24	36	48
0	1.31	1.62	1 62	1.62	1.62
20	1.31	1.55	1.83	1.49	1 39
25	1.31	1.59	1.87	1.51	1.41
30	1.31	1.65	1.99	1.58	1.43
35	1.31	1.71	2 00	1.63	1.45
40	1.31	1.54	1 93	1 87	1.79

From the data presented in Tables 3 and 4, it could be easily inferred that with the increase of temperature the levels of both organic and inorganic phosphorus were also affected. At 0° C there was practically on change in the levels of phosphorus. The levels of phosphorus changed very little at this temperature, because practically no metabolic change could possibly take place at such a low temperature. From 20° C to 25° C the level of the inorganic phosphorus decreased rapidly but again it started increasing and this increase was maintained after 48 hours of germination. The level of organic phosphorus also increased with the increase of temperature upto 35° C for the first 24 hours of germination but above this temperature the increase of organic phosphorus in the first 24 hours was slower as compared to that obtained at 35° C.

Phosphorus metabolism of the seeds of *Phaseolus radiatus* was also studied with the seeds treated with ortho-fluoro phenoxy alpha methyl acetic acid. The results obtained have been tabulated in Tables 5 and 6.

Table 5.—Changes in the level of inorganic phosphorus level in the seeds treated with ortho-fluoro phenoxy alpha methyl acetic acid

Concentration of ortho fluoro phenoxy alpha methyl acetic acid in ppm	Concentration of inorganic phosphorus in mg gm			
	Time in hours			
	12	24	36	48
Control	0.21	0 102	0.15	0 17
1	0.18	0.135	0 145	0.158
5	0 18	0.141	0 149	0 152
25	0.17	0 161	0 158	0 155
50	0 17	0 167	0.163	0.163

Table 6.—Changes in the level of organic phosphorus in the seeds treated with ortho-fluoro phenoxy alpha methyl acetic acid

Concentration of ortho fluoro phenoxy alpha methyl acetic acid in ppm	Organic phosphorus in mg gm			
	Time in hours			
	12	24	36	48
Control	1 71	2 12	1 63	1.43
1	1.68	1.83	1 91	1 89
5	1.68	1 95	1.87	1 89
25	1.65	1 83	1.85	1.85
50	1.66	1.67	1 67	1 67

From the data presented in Tables 5 and 6 it could be inferred that treatment of the seeds with ortho-fluoro-phenoxy-alpha-methyl acetic acid adversely affected the phosphorus metabolism. Both the organic and inorganic phosphorus levels indicated a decline till a standstill condition was arrived at with 50 ppm of the chemical.

It has been generally believed that one of the chief functions of the biological machinery has been to generate energy. The phenomenon of growth might be construed as representing a series of complex reactions, and so naturally growth should be related to the continuous synthesis of energy rich compounds, i.e. the generation of substance like ATP which, might be produced by the oxidation of the substances like carbohydrates or other metabolic substrates or by photophosphorylation (Arnon, 1960). There must be a source of the supply of inorganic phosphates. The seeds would be expected to contain enogh phosphorus to meet this early demand for growth. As the seeds begin to increase in size they would need phosphorus from an exogenous source. In the case of deficiency of phosphorus in the environment, their growth would be severely affected.

In monocots, like oats, very little phosphorus has been reported to be found in the seeds. Albaum and Umbreit (1943) have reported an increase in the level of inorganic phosphorus during the germination of oat seeds. They have further reported that phosphorus was found in the form of phytic acid. This phytic acid did not occur in the free state but as salts of calcium and magnesium. McCance and Widdowson (1935) have found phytin in the seeds of peanuts, peas, potatoes and carrots. Fontaine *et al.* (1946) have reported that in some cases phosphorus is found in a bound state with proteins.

In the seeds of *Phaseolus radiatus* a small amount of inorganic phosphorus was possibly utilized in the formation of ATP to start the metabolic mechanism. As a result of this the level of the inorganic phosphorus inevitably falls rapidly. But after 36 hours it was observed that its level again began to rise. This increase might be due to the liberation of phosphorus from phytin by the action of phytase as has been reported by several authors. But the present author (Tewari, 1965), on the basis of his studies with phosphorylase, would be inclined to believe that the liberation of inorganic phosphorus after 36 hours of germination might be due to an increase in phosphorylase activity. Phosphorylase activity was found by him to be correlated directly with

the concentration of inorganic phosphates. Tewari (1965) has also noticed a decline in phosphorylase activity in the seeds treated with the inhibitor.

An increase in temperature upto 35°C led to the disappearance of inorganic phosphorus. But above 35°C the phosphorus metabolism was affected adversely and the level of phosphorus decreased. If only phytase would have been responsible for the liberation of inorganic phosphorus, then the level would have gone up because phytase has been reported to be active upto a temperature of 50°C. Phosphorylase was found to be adversely affected at a temperature above 35°C and this probably would explain why the rate of the liberation of inorganic phosphates was slowed down.

The utilization of inorganic phosphorus in light did not appear to be very important during the early stages of germination. The seeds grown in light and red light did not indicate a higher rate of disappearance of orthophosphate. On this basis it appeared reasonable to conclude that oxidative phosphorylation played a very important role during the early hours of germination than the photosynthetic phosphorylation either cyclic or noncyclic (Arnon, 1960).

IV—SUMMARY

Phaseolus radiatus Linn. is cultivated in many parts of Rajasthan for its protein value. The changes in the level of organic and inorganic phosphorus during seed germination as influenced by ortho fluoro-alpha-methyl acetic acid, a growth inhibitor, were studied. The level of the inorganic phosphorus steadily decreased in the first 24 hours of germination and then started increasing, while the converse held true in the case of organic phosphorus. The inorganic phosphorus was converted to organic phosphorus by the enzyme phosphortylase. Ortho-fluoro-alpha-methyl acetic acid strongly inhibited the phosphorus metabolism even at a concentration of 5 ppm. Its inhibitory effect appears to be related with the phosphorus metabolism of the seeds during germination.

Phosphorus metabolism was also studied in the seeds germinated at different temperatures. The best conversion of phosphorus could be found at 35°C which was optimum for phosphorylase activity. It is con-

cluded that initial phosphate liberation from organic phosphates is by phosphorylase and not by phytase.

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INHIBITION OF GROWTH OF *PHASEOLUS RADIATUS* LINN. FROM FRUIT EXTRACTS OF *SALVADORA OLEOIDES* DECNE

By

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(With 1 Table)

I—Introduction

Many substances have been reported to inhibit the germination and growth of the seedlings from the fruits and seeds of the higher plants. Evanari (1949) has made a survey of occurrence of such inhibitors in higher plants. Shuck (1935), Wareing and Foda (1956-57), Poljakoff-Mayber *et al.* (1956) have reported the presence of an inhibitor in lettuce seeds. Luckwill (1952) has reported two inhibitors from unripe fruits of *Asparagus*. Asakawa (1954) found an inhibitor in the fruit of *Fraxinus*. An inhibitory principle was also reported in the pericarp of birch seeds by Black (1957).

In the present investigations the authors were interested to find out involvement of an inhibitory substance in the fruits of *Salvadora oleoides*. Large number of fruits are produced every year from the plants but the germination is extremely poor, so even if the plant is very well adapted to arid conditions it could not be used for afforestation purposes due to the poor germination of the seeds. In nature seeds remain encased in fruits and only 10% germination could be obtained though seeds showed 100% imbibition. This gave an indication about the possible presence of some growth inhibitor in the fruits.

II—Material and Methods

The fruits were broken to remove the seeds and the shell was powdered. 2 g of this powder was boiled for one hour and the content was filtered. The filtrate was made up to 50 ml and ten seeds of *Phaseolus radiatus* were soaked in this solution for six hours at room temperature. Seeds were washed with distilled water and were germinated in sterilized petridishes lined with moist filter paper. A control

was also run in which seeds were soaked in distilled water and were germinated as treated ones.

An attempt was also made to determine the Rf of the inhibitor. For this purpose 2 g of the powder was boiled for one hour. After filtration the volume of the filtrate was reduced to 1 ml by further boiling. 0.5 ml of the solution was spotted on silica-gel layer (0.5 mm thick) for Chromatography. 6.0% acetic acid was used as Chromatographic solvent. A blank silica-gel coated plate was also run in the same solution as control. After drying the plates in an oven at 60°C for 30 minutes 2 sq cm silica-gel columns from different heights were removed. The content was disolved in 10 ml of distilled water. The seeds of *Phaseolus radiatus* Linn. were soaked in all these solutions for six hours and after washing with distilled water they were allowed to germinate as mentioned above.

III—RESULTS AND DISCUSSION

The seeds soaked in distilled water and the solution of fruit wall did not indicate any difference in imbibition but a marked difference was found in the average growth of the seedlings which has been presented in Table 1.

Table 1.—Average growth of seedlings

Days	Average length of seedlings in millimetres	
	Control	Treated
1	9	0
2	18	3
3	26	8
4	45	9
5	62	10
6	67	11
7	85	11 6

It was found from the substances recovered from the Chromatographic plate that hardly any growth of the seedlings took place by the treatment of the solution which was obtained from the silica-gel Chromatographic plate at Rf 0.8.

The growth was more or less completely inhibited by the substance obtained at Rf 0.8. This might be the reason for the failure of the germination of the seeds of *Salvadora oleoides* in nature. The inhibitor

appeared water soluble having an Rf 0.8 in 6% acetic acid at 25°C on Silicagel layer(0.5 mm thick) Chromatograph. The inhibitor may be an antiauxin or a substance which interfered with the initial metabolism.

IV—ACKNOWLEDGEMENTS

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V—SUMMARY

The seeds of *Salvadora oleoides* Decne show very poor germination in nature but they always indicated 100% imbibition. This gave an idea of possible occurrence of some inhibitor in the fruits which inhibited the growth of the seeds because seeds remain enclosed in the fruits. In the present work we have noticed a water soluble inhibitory substance from the fruits of *Salvadora oleoides* Decne which strongly inhibited the growth of the seeds of *Phaseolus radiatus* Linn. The Rf value of the inhibitor was 0.8 on Silica-gel layer (0.5 mm thick) chromatograph using 6.0% acetic acid as solvent at 25°C.

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LEAFLESS *EUPHORBIA* ON RAJASTHAN (INDIA) ROCKS. III. OBSERVATIONS IN WATER RELATIONS

By

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(With 4 Tables)

I—Introduction

Euphorbia caducifolia Haines is stated as a characteristic plant species on sandstone or gravel in a major part of Rajasthan. Water is mainly available in rainy season and its scarcity is felt almost throughout the year. This species occupies a slopy habitat where a quick run of water takes place when it is at all available in a short rainy season. In spite of extreme scarcity of water this species flourishes well under these ecological conditions. A few papers on different aspects of ecological life history have already been published (Sen, 1965, 1968a, 1968b, Sen and Chatterji, 1966, Sen and Chawan, 1972).

Shull (1916) and Kaul (1968) measured the force of attraction of air dry seeds of *Xanthium* species (*X. pennsylvanicum* and *X. strumarium*) for water, using different concentrations of solutions of sodium chloride and determined the intake of water by the seeds in each solution. The water relations of seeds, seedlings and adult plants have been worked out after a number of field and laboratory observations on leafless *Euphorbia*, which is a photosynthesising, perennating, latex containing, fleshy plant and remains leafless for the major part of the year. The plant dries extremely slowly even when uprooted, showing thereby that it has a great capacity for absorbing and retaining water under extreme xeric conditions of the environment.

In order to find out the water relations of this species under extreme scarcity of water availability a detailed analysis was carried out on some six selected plants growing in their natural habitat.

II—Material and Methods

A few individual plants were marked in the field from which samples of latex, leaves and stems were brought to the laboratory for

analysis either fortnightly or monthly. The first leaf samples were collected for observations in the first week of August 1968 till the time of leaf fall.

In order to find out the water content in different parts of plant, the samples were oven dried and calculations were done on fresh weight basis.

The force of attraction of water by the seeds was measured by using different concentrations of solutions of sodium chloride. The intake of water by the seeds was determined in each solutions for a particular duration of time.

III—OBSERVATIONS

1. Water Relations

Latex: *Euphorbia caducifolia* ramains characteristically leafless for more than three fourth of the year, so that the amount of water present in the leaves presumably does not affect very much the metabolic process of the plant. This is because the leafless phylloclades possess an abundant amount of water in the latex. The presence of latex in all plant parts is an important physiological factor, and the amount of latex in the plant indirectly exhibits the water content in the plant. Since the water content in a sample by weight differs in different individual plants and this difference remained distinct with the change of seasons, an analysis of the same was done which has been shown in Table 1.

It is evident from Table 1 that water content in the latex of six individual plants varied at the end of late rainy season (15th Oct., 1968). It was minimum (80.3%) in sample No. 3 and maximum in sample No. 2. The percentage of water content in sample Nos. 1, 4 and 5 did not vary very much under similar enviornmental conditions. The values of water percentage changed to a very great extent in the month of December 1968, when the weather was extremely cold and desiccating. It was minimum (61.7%) in sample No. 6 and maximum (75.9%) in sample No. 4. There were no significant differences in the percentage of water content in the sample Nos. 1 and 5.

An increase in the water percentage could be observed at the end of January 1969 due to rains which fell during the months of January 1969, which caused an abrupt increase in the water percentage of

Table I.—Percentage of content in latex (Lx) and stem (S) of six individual plants of Euphorbia caducifolia

Plant No.	Dates [illegible] Lx	S	15-10-68 Lx	S	14-11-68 Lx	S	20-12-68 Lx	S	31-1-69 Lx	S	28-2-69 Lx	S
1	73.7 ± 2.5	[illegible] ± 0.6	83.4 ± 1.1	91.3 ± 1.2	77.9 ± 1.6	91.1 ± 2.5	71.6 ± 3.2	87.2 ± 2.0	76.6 ± 2.0	89.5 ± 0.4	68.0 ± 3.0	89.0 ± 1.0
2	69.8 ± 1.2	90.0 ± 0.4	90.2 ± 0.7	92.4 ± 1.1	67.4 ± 2.0	89.9 ± 1.2	66.4 ± 2.0	88.1 ± 2.0	70.6 ± 3.0	88.7 ± 0.6	68.3 ± 1.0	87.6 ± 1.0
3	74.2 ± 0.8	71.2 ± 0.8	[illegible] ± 1.7	92.4 ± 1.3	75.5 ± 1.7	90.2 ± 1.0	73.2 ± 2.7	88.7 ± 1.3	73.1 ± 1.0	88.1 ± 1.2	72.4 ± 1.2	87.3 ± 0.5
4	73.3 ± 2.6	87.2 ± 0.6	82.4 ± 1.4	91.7 ± 1.0	69.8 ± 2.6	88.3 ± 1.3	75.9 ± 2.0	87.3 ± 2.9	77.1 ± 1.0	94.0 ± 2.0	75.3 ± 2.0	81.9 ± 6.0
5	69.6 ± 2.1	86.6 ± 0.6	81.5 ± 1.6	93.3 ± 2.3	74.2 ± 1.2	89.4 ± 1.4	71.8 ± 7.0	87.4 ± 2.0	78.7 ± 1.6	88.0 ± 0.5	71.7 ± 1.0	87.8 ± 2.0
6	[illegible] ± 2.8	[illegible] ± 3.1	[illegible] ± 0.9	91.3 ± 1.0	69.1 ± 2.0	87.6 ± 1.0	61.7 ± 2.8	86.6 ± 2.0	65.8 ± 2.0	88.5 ± 1.5	68.8 ± 1.0	85.3 ± 1.0

latex in all the six individual samples of *E. caducifolia*. A noticeable increase in percentage of water could be observed in sample Nos. 1, 2, 5 and 6, which ranged from 4 to 7 percent. In sample No. 4, it was significant but insignificant in sample No. 3. At the end of February the percentage of water mostly showed a slight fall except for sample No. 6 for latex, where the percentage increased.

Stem : Besides latex, water present in other tissues of stem and leaves, has also been analysed in the present study. The percentage of water present in the stem apex is presented in Table 1.

Comparing the data presented in Table 1 for the percentage of water content in the latex taken from the stem and that of stem itself at the start of the observations on 15th Oct., 1968, it appeared that the percentage remained higher in the stem. Table 1 also exhibits that the percentage of water in the stem always universally remained higher as compared to water percentage in latex system. It is also evident that the water content in the six different samples of stem did not vary very much, on 15th Oct., 1968 or during or at the end of the observation period.

Leaf : *E. caducifolia* bears leaves for a short duration in late summer and early rainy season. There exists great morphological variations in the leaves. The appearance and fall of leaves take place due to an endogenous cyclic rhythm at its fixed time quite independent of the prevailing ecological conditions. It is true that the foliage of some plants became dull green earlier than the others, then progressively brownish or yellowish red as they were shed. Leaves did not exactly show wilting due to their fleshy nature, but appeared shrunken. They became dry and brittle, and ultimately turned red brown, but were retained on the plants for quite sometime (Sen and Chawan, 1972). Since water content of the leaves play an important role in retaining these on the plants, the water percentage of leaves on six individual plants at different intervals of time has been tabulated in Table 2.

Table 2.—Percentage of water content in the leaves of six individual plants of Euphorbia caducifolia *at various intervals of observation peroid*

Plant No.	Young leaves 14-7-68	Mature leaves 4-8-68	Mature leaves 15-10-68	Falling leaves (Oct.-Nov. 68)
1	93.3 ± 0.6	91.1 ± 0.7	91.7 ± 1.7	66.3 ± 2.3
2	92.6 ± 0.7	90.7 ± 0.7	93.2 ± 0.8	63.4 ± 2.7
3	90.6 ± 0.6	90.0 ± 0.2	95.6 ± 1.5	66.4 ± 2.1
4	91.4 + 0.4	90.1 ± 0.1	92.2 ± 0.8	69.7 ± 7.6
5	92.4 ± 0.5	91.8 ± 0.3	92.8 ± 0.4	69.6 ± 2.1
6	92.3 ± 0.4	92.1 ± 0.2	92.4 ± 0.7	70.0 ± 2.0

It is evident from Table 2 that water content in the six samples did not vary very much in the young leaf samples. There was fluctuation, during the different observations, in the percentage of water content in all the six samples of leaves. However, a decrease of 20 to 25 percent in the moisture percentage of leaves caused the falling of leaves from the phyllocladous stem.

Fruits and Seeds : The percentage of water content in the fruit wall and seeds at the time of dispersal has also been estimated, and presented in Table 3.

It is evident from Table 3 that the dehiscing fruit wall contains very little water. The decrease of water in the fruit wall causes its explosion. Even the seeds almost always contained more water than their fruit walls. The percentage of water both in the fruit wall and the seeds vary in all the individual plants analysed.

2. *Water Requirement of Seeds*

The force of attraction of water by *Euphorbia* seeds using different concentrations of sodium chloride (0.10 M, 0.25 M, 0.50 M, 0.75 M, 1.00 M, 2.00 M, 4.00 M and saturated solutions) was measured. Air dried seeds were kept in sodium chloride solutions of different concentrations for a period of 3, 6, 12 and 24 hours. The percentage of moisture intake by seeds during different durations was calculated on the air dried weight of seeds, and is discussed below.

It has been observed that the seeds of *E. caducifolia* absorbed water from all concentrations examined at 25°C. In seeds of sample No. 2, there was a steady rise in the intake of water even after a duration of 24 hours. The intake of water was very significant within first three hours till a solution of 2.00 M, concentration, beyond which it was insignificant. In seeds of sample No. 5, there was almost no water intake beyond six hours duration even in those seeds which were kept in distilled water. In fact, water was withdrawn when the seeds were kept for longer duration in high molar solutions of sodium chloride. In seeds from sample No. 6, there was a significant increase in the intake of water in three to six hours duration, but beyond six hours mostly there has been a withdrawal of absorbed water. Within twentyfour hours, the absorption of water by seeds in distilled water has been more than hundred percent, although this has not been so high in sample Nos. 2 and 5. Thus it was evident that the seeds have a capacity to absorb moisture from solutions of high osmotic concentrations.

3. *Stomatal Index*

A study of stomata was made from the peelings of six samples both from the lower and upper surfaces of the leaves. The number of stomata and epidermal cells with their stomatal index is shown in Table 4.

Table 4. Number of stomata and epidermal cells per unit area and stomatal index in the leaves and stem of six individual plants of Euphorbia caducifolia

Plant No.	Number of stomata in leaves		Number of epidermal cells in leaves		Stem		Stomatal index		
	Upper epidermis	Lower epidermis	Upper epidermis	Lower epidermis	Number of stomata	Number of epidermal cells	Upper epidermis	Lower epidermis	Stem
1	53	80	1184	790	53	3421	4.2	9.2	1.5
2	80	53	1368	1000	53	3158	5.5	5.0	1.0
3	80	53	895	658	26	3368	8.2	7.3	0.7
4	131	80	921	895	53	3289	12.4	8.2	1.5
5	80	80	947	1092	26	3789	7.7	7.0	0.6
6	26	80	1473	1052	53	3368	1.7	7.0	7.5

Table 4 gives an indication of the stomatal index in the upper and lower surfaces of the leaves and the stem. The values run parallel for lower and upper surfaces of leaves except for sample No. 1, where it was more than twice, and for sample No. 6, thrice in lower surface as compared to the upper. The stomatal index for stem was uniform in all the samples, but the values are slightly lower for sample Nos. 3 and 5. It would be evident from these observations that the stem did not possess any efficient means of gaseous exchange after the leaf fall.

IV—DISCUSSION

A comparison of the individual plants used in the present study points to the unmistakable fact that *Euphorbia caducifolia* exhibited a diversity of a remarkable magnitude. This diversity was reflected in the water relations of *E. caducifolia*. The leaves appeared when the plants had almost no water available in the soil and were shed when the water availability was ample. An extremely parallel example in *Sarcostemma aicdum*, *Capparis decidua* and *Leptadenia pyrotechnica* have been observed (Sen and Chawan, 1972).

Stocker (1956) has reported that the desert plants appear to restrict loss of water by substantially diminishing the rate of transpiration by keeping stomata half open. The leaves in case of *E. caducifolia* were shed which had far larger number of stomata, as compared to stem. The number of stomata was either half or even less than one-fourth per unit area on stem as compared to leaf and thus the water loss was reduced to a remarkable degree in this plant.

The water percentage in rainy season of young stem, mature stem and young leaves in *Zizyphus nummularia* growing on rocky habitat had been estimated as 58.11%, 53.44% and 55.29% respectively (Nanda, 1967). Sen and Chawan (1972) observed that during rainy season the water in *E. caducifolia* remained higher in newly grown on stem as compared to old stem or leaf. During the present study the same plants in early winter season have been observed to possess higher percentage of water which gradually decreased with the dry desiccating winds of winter season in the stem. However, the water content in leaves was little higher than the stems, but it suddenly decreased.

Kaul (1968) showed that seeds of *Xanthium strumarium* absorbed water from 0.1 to 6.0 M concentrations of sodium chloride solutions at 25.6°C.

This has been partly confirmed in the above observations, because beyond 2.0 M concentrations water absorption was insignificant.

The above mentioned facts point to the conclusion that the water metabolism play a significant role in the adaptation of leafless *Euphorbia*, to the desert. The morphological adaptations, whether due to ecological or genetic reasons, govern the physiology of water in the latex or in the succulent tissues of the plants.

V—SUMMARY

Leafless spurge, *Euphorbia caducifolia* Hains, is grouped as a characteristic species in plant communities on sandstone or gravel in a major part of Rajasthan. Except for a short rainy season, water availability to this species remains a problem throughout the year. This is more so due to the occurrence of this plant in slopy habitats. In spite of extremely xeric conditions, the species flourishes well.

Euphorbia is a photosynthesising, perennating, spiny and latex containing plant which remains so for major part of the year. Even the uprooted plants grew and their drying was extremely slow, thus exhibiting a great capacity for absorbing and retaining water. It showed the remarkable potentiality of the species that it maintained its formal metabolic activity and remained living in spite of abundant water loss.

The appearance of leaves in late summer and their fall in late rainy season seemed to be an endogenous rhythmic phenomenon.

This species possesses abundance of latex which may be the reason that it did not suffer at all under high desiccation of the environment. The amount and the quality of latex in the plants indirectly exhibited their water content, which was found to differ from plant to plant even in the same population. The percentage of water content in the latex from the stem was as low as 48.7% in one sample and as high as 90.2% in another.

At the time of leaf appearance, there is new growth in the stem as well. This newly-grown part was found to have higher percentage of water as compared to old stem or even leaves, although newly-grown stem and leaves appear simultaneously. It was found that water content of leaves from different individual plants did not vary much.

The range of relative moisture content in the old stem in early August was as low as 41.2 in some, while as high as 90.6 in others. This

species remains leafless in summers when there was a possibility of some visible signs of water stression from the leaves.

The best germination of seeds and the further growth of seedlings was evident in rainy season, as the leaves appeared in quick succession at that time.

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Discussion

S C Pandeya : The small 4 months old seedling of *Euphorbia* kept in laboratory give out leaves. The photo and RH conditions differ here. Did you work it and also kept a plant in open ?

D.N. Sen : The seedling of *E. caducifolia* in question was not 4 months old. It was about 3 years old. The appearance of leaves in any four months of a year is not possible, because leaves are borne by plants for only 3-5 months only once in a year in late summer to early rainfall. The primary aim to keep the plants in an uprooted condition in the laboratory was to disconnect the roots from the soil and any other water supply. And even after this disconnection in water supply the plants behaved normally and in their due season bore leaves as wall, which was an evidence of their metabolic activity.

S C. Pandeya : Your plant appears to be xeromorphic and not xerophytic. It could have been better confirmed by O P. determination at different stages.

D N. Sen O P. determination of a number of plants and their parts such as old stem, newly-grown stem, and leaves were determined. The O.P. values ranged from 14 3 34 6 atm. and only in one case of old stem, the value was higher than 65.8 atm. Species of Arizona desert have been reported to have an average O P. of 20 atm. The plant, of course, has some xeromorphic features.

S C. Pandeya : Did you work the cytology and inter breeding between the 3 forms you have distinguished ?

D N. Sen : I stated in the very beginning that I have not worked out the cytology of the plant as yet, which I intend to do now.

S.C. Pandeya : Are the populations mixed or show specific ecological distribution ?

D.N. Sen : In one population there are different types of plants distributed and they do not have specific ecological distribution. This I have shown very clearly in my coloured slide where green and red inflorescence forms were growing very near each other.

A N. Lahiri : Does the sprouting of leaf in plants kept in laboratory for 3 months suggests that bound water is somehow related with this phenomenon ?

D N. Sen : Bound water is inactive physiologically I cannot say anything in detail about this. But leaves always appear at their particular season of the year as an endogenous rhythmic cycle

P.C. Nanda : While determining colour forms in *Euphorbia caducifolia* did you make any variability index to fix each form ?

D.N. Sen : No

P.C Nanda : While collecting seeds of different size, shape and weight did you take into account microclimate of different sites of collection ?

D N. Sen : Micro climate did not appear to be operative as regards morphological variation, since a group of plants in the same microclimate showed variability.

A N. Lahiri : Do the seeds obtained from plants having red flowers produce plants with red flowers ?

D.N. Sen : The species is an extremely slow growing one and so this could not be observed as yet.

A K. Chakravarty : The speaker mentioned some variability in seed, stem and flower characters in plants of *E. caducifolia* in nature. Has any study been made to classify the different types on the basis of variation observed ? If so, with what results ?

D N. Sen : This difference in colour, mottling, etc., was first noticed in seeds a few years back. Later on other variability in other parts was also noted.

S K. Jain : *Euphorbia caducifolia* is a xerophyte. Its succulent stems, caducous leaves, stipular spines, and above all its habitat do show that it is a xerophytic plant.

D N. Sen : The characters mentioned by you are some xeromorphic features of plants. The stem remains fleshy water or no water. The leaves fall down at their seasons whether it rains or not Their appearance takes place in late summer when there is a extreme shortage of water in the soil and the air environments. The appearance and disappearance of these features are probably governed by an endogenous rhythmic cycle.

THE EFFECT OF DROUGHT ON THE TURNOVER OF BOUND AND FREE ASCORBIC ACID AND ITS UTILIZATION IN GERMINATING BARLEY

By

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(With 3 Text-figures)

I—Introduction

It has been shown that the concentration of free ascorbic acid in plants increases during a period of drought (Stocker, 1956, 1961; Solomon, 1955; Startseva, 1963; Shcherbakov, 1963; Chinoy, 1964-67). This fact suggests that ascorbic acid may be playing a protective role during the condition of water stress. The purpose of the present paper is to elucidate some of these points.

II—Experimental Procedure

Seedlings of two varieties of barley were subjected to desiccation in chambers maintained at low humidity at 25±3°C for five and ten days respectively. At the end of the appropriate desiccation period seedlings were revived by moistening the sterilized sand of the Petri dish in which they were kept for germination. The seedlings were considered as having revived when they reached the succeeding stage of seedling growth to the one at which they were given the desiccation treatment. After separating the embryo axis from the endosperm, ascorbic acid and ascorbigen concentrations as well as ascorbic acid utilization were determined in duplicate at three stages, viz. (i) before the initiation of the desiccation treatment, (ii) just before the termination of the desiccation period, and (iii) after revival.

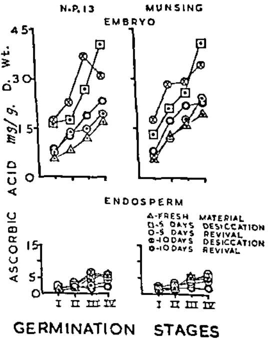
Ascorbic acid (AA) and ascorbic acid utilization (AAU) were estimated titrimetrically, employing 2, 6-dichlorophenolindophenol method developed in this laboratory (Chinoy, 1962). The ascorbigen (ASG) was estimated by releasing AA by hydrolysis with 5% metaphosphoric acid in a boiling water bath for 10 minutes, adding the

requisite quantity of the dye solution and titrating against standard AA solution as before. The free AA content was subtracted from total AA thus obtained to get the value of ASG expressed as mg AA per g dry weight of plant material.

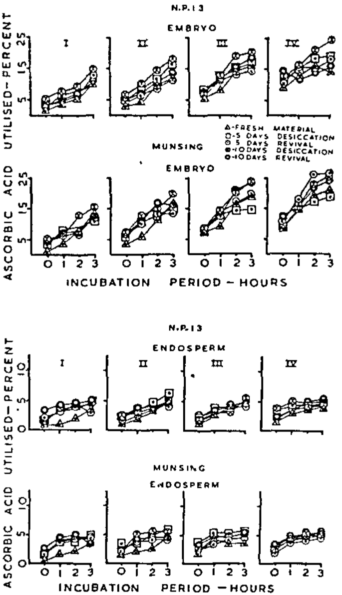
The data were analysed statistically using Fisher's method of analysis of variance.

III—EXPERIMENTAL FINDINGS

The concentration of ascorbic acid, ascorbigen and ascorbic acid utilization in the embryo axis of both the varieties is invariably higher compared to that of the endosperm. There is an enhancement in ascorbic acid concentration and its utilization with advance in germination. Embryo axis receiving 10-day desiccation shows consistently a higher concentration of AA. Its utilization is also higher in both the varieties at all stages of growth when compared with that of undesiccated or revived seedlings (Text figs. 1 and 2). It may also be noted that the



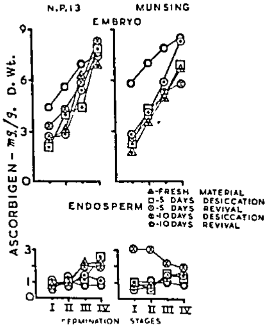
Text-fig. 1—Free ascorbic acid (AA) content in embryo axis and endosperm during different desiccation treatments.



Text-fig. 2—Ascorbic acid utilization (AAU) per cent in embryo axis and endosperm during different desiccation treatments.

ascorbic acid content and its utilization are at higher levels in the revived seedlings compared to those of undesiccated ones. Ascorbigen content of seedlings revived after 10-day desiccation is the highest in

both the varieties followed by those seedlings which were revived after undergoing 5 days desiccation (Text fig. 3) Ascorbigen content of



Text-fig. 3—Ascorbigen (bound ascorbic acid-ASG) content in embryo axis and endosperm during different desiccation treatments.

embryo axis which had undergone desiccation for 5 and 10 days respectively and also of undesiccated ones is lower compared to that of embryo axis which had recovered from desiccation. The endosperm of 10-day desiccated embryo axis of Munsing also contains higher ascorbigen content.

Analysis of variance was carried out on data of ascorbic acid and ascorbigen contents as well as ascorbic acid utilization. Effects of desiccation on AA and ASG contents as well as on AAU were found to be highly significant.

IV—Discussion

It is evident from the data presented here that ascorbic acid content as well as its utilization are enhanced during desiccation. Ascorbigen content also shows interesting fluctuations. Ascorbic acid is at a higher level in the case of desiccated seedlings compared to that

in fresh material. This increase in the concentration of free ascorbic acid probably plays a vital role in maintaining the redox balance in the seedling on the reductive side which is so essential for synthetic activity in the plant for maintaining growth. Stocker (1956, 1961) has considered the ratio of oxidized/reduced ascorbic acid as a relative measure of the redox potential. Total ascorbic acid was found to increase considerably under extreme drought conditions. Stocker (1961) showed that an inordinately high oxidation-reduction quotient, high total ascorbic acid and high respiration during a period of extreme drought preceded a complete breakdown of metabolism.

Even in the case of drought of moderate intensity, as in the present experiment, where the desiccated seedlings make vigorous growth after revival, the concentration of free ascorbic acid reaches a higher level during the period of drought. This appears to stimulate some enzymatic processes like amylase and lipase as seen from the enhancement in their hydrolytic activity during desiccation most probably by creating a reductive environment (Chinoy, 1964-67; Chinoy et. al., 1968; also see review article on "Drought resistance in crop plants" in this volume).

The fall in the concentration of free ascorbic acid during the process of revival and a concomitant rise in its bound form clearly indicates the active metabolic turnover of ascorbic acid.

V—ACKNOWLEDGEMENT

Thanks are due to United States Department of Agriculture for financing the P.L. 480 Research Project, FG-In-208(A7-CR-108), entitled "Physiological studies of drought resistance in some Indian and American varieties of barley" of which the data presented here forms a part.

VI—SUMMARY

Seeds of barley N.P. 13 (Indian variety) and Munsing (American variety) were germinated upto various stages and subjected to desiccation. The seedlings were subsequently revived. Turnover of bound (ascorbigen) and free ascorbic acid as well as its utilization were studied in undesiccated and desiccated seedlings as well as after their revival at different stages of growth. Free ascorbic acid was found to increase significantly in desiccated seedlings, whereas the bound ascorbic acid decreased under desiccation. However, on revival of seedlings from the effect of

drought there was a significant fall in the concentration of free ascorbic acid and an equally significant rise in ascorbigen content of the revived seedlings.

On the basis of these findings as well as taking into account the studies of enzymatic processes under the influence of drought carried out in our laboratory it has been suggested that increase in the concentration of free ascorbic acid during desiccation stimulates hydrolytic activity of amylase and lipase most probably by creating a reductive environment. The fall in the concentration of free ascorbic acid during the process of revival and a concomitant rise in its bound form clearly indicates the active metabolic turnover of ascorbic acid.

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VITAMIN C IN RELATION TO WATER UPTAKE AND GROWTH OF SOME DESERT PLANTS. I. *TEPHROSIA*

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(With 2 Tables)

I—INTRODUCTION

Tephrosia occurs luxuriantly in the Indian desert. The plant is well adapted to xeric conditions and helps in stabilizing the sand. The function and biosynthesis of ascorbic acid in plants has recently been reviewed by Aberg (1958) and Mapson (1958). There are divergent reports about the role of ascorbic acid in the growth of seedlings. In the present investigation an attempt has been made to study the relations between ascorbic acid and water uptake and growth, if any. An attempt has also been made to study relationship between ascorbic acid synthesis and added ascorbic acid on growth of the seedlings of *T. purpurea* and *T. vilosa.*

II—MATERIAL AND METHODS

The seeds of *Tephrosia purpurea* and *T. vilosa* were collected from the field and stored in glass stoppered bottles at room temperature. The seeds were treated with concentrated sulphuric acid for fifteen minutes, washed, weighed after drying with blotting paper, and thereafter were kept in different concentrations of ascorbic acid. After 24 hours of soaking at 30±2°C the seeds were again weighed after blotting the surface water. For all the concentrations ten replicates, each containing ten seeds, were used.

To study the growth, the seeds were soaked in different concentrations of ascorbic acid for six hours after the pretreatment with concentrated sulphuric acid for fifteen minutes. The seeds were allowed to germinate in sterilized petridishes lined with filter paper at 30±2°C in continuous light. The length of the seedlings was measured after every 24 hours for seven days.

The ascorbic acid was estimated by the titrametric method. The seeds after 50 hours of germination, as described above, were homogenized with 5% metaphosphoric acid to extract the ascorbic acid. The filterate was titrated against 0.025% 2-6-dichlorophenolindiphenol after standardizing the dye with a known concentration of ascorbic acid.

Table 1.—Water uptake as affected by ascorbic acid
(Figures in brackets show standard deviation.)

Conc. of ascorbic acid in ppm	Water imbibied after 24 hours in ml	
	T. purpurea	*T. villosa*
Control	0.1354 (±0.0012)	0.0093 (±0.0011)
1	0.1658 (±0.0026)	0.0118 (±0.0031)
5	0.1683 (±0.0010)	0.0163 (±0.0023)
10	0.1918 (±0.0009)	0.0245 (±0.0016)
25	0.1350 (±0.0012)	0.0156 (±0.0019)
50	0.1616 (±0.0014)	0.0155 (±0.0013)
100	0.1762 (±0.0017)	0.0160 (±0.0026)
1000	0.1322 (±0.0024)	0.0130 (±0.0012)

III—RESULTS AND DISCUSSION

The seeds have a hard seed coat which not only inhibits the initial water uptake but also mechanically suppresses the embryo to grow and to break it. After pretreatment with concentrated sulphuric acid for fifteen minutes the seeds absorbed water and germinated. The water uptake as affected by ascorbic acid is shown in Table 1. Ascorbic acid increased the water uptake of the seeds upto a concentration of 100 ppm, but at higher concentrations the water uptake declined. Also at 25 ppm a sudden decline in water uptake was recorded.

The growth of the seedlings as affected by ascorbic acid is shown in the Table 2. The seeds treated with ascorbic acid showed better growth upto a concentration of 100 ppm. At higher concentrations the growth was retarded. At a concentration of 25 ppm seeds showed poor growth though at 5 ppm and 10 ppm the growth was better over the controls. Havas (1935), working on wheat, has reported the higher concentrations of ascorbic acid to be inhibitory or mortal. Davies *et al.* (1937) working on cress and mustard, Mitra and Dutta (1951) working on jute, and Lee (1955) working on Lupine and tomato have reported

Table 2.—Effect of vitamin C on the growth of young seedlings of Tephrosia

Conc. of AA in ppm	Plant	1	2	3	4	5	6	7
Control	*T. purpurea*	1	4 (1+3)	8 (3+5)	11 (4+7)	15 (6+9)	19 (8+11)	20 (8+12)
	T. vilosa	2	5 (2+3)	9 (4+5)	14 (6+8)	18 (8+10)	20 (9+11)	22 (9+13)
1	*T. purpurea*	1	5 (4+1)	9 (6+3)	14 (7+7)	17 (7+10)	21 (9+12)	25 (10+15)
	T. vilosa	2	6 (4+2)	11 (6+5)	15 (7+8)	20 (9+11)	24 (11+13)	27 (12+15)
5	*T. purpurea*	2	8 (5+3)	13 (7+6)	20 (9+11)	29 (12+17)	36 (12+24)	44 (14+30)
	T. vilosa	2	7 (4+3)	12 (6+6)	17 (8+9)	24 (10+14)	28 (11+17)	32 (13+19)
10	*T. purpurea*	6	13 (6+7)	25 (10+15)	31 (10+21)	40 (17+23)	49 (20+29)	56 (22+34)
	T vilosa	4	9 (6+3)	15 (8+7)	21 (10+11)	27 (13+14)	32 (15+17)	36 (16+20)
25	*T. purpurea*	3	7 (4+3)	9 (5+4)	14 (6+8)	20 (8+12)	26 (9+15)	30 (10+20)
	T. vilosa	3	7 (4+3)	12 (6+6)	17 (8+9)	23 (10+13)	29 (12+17)	34 (14+20)
50	*T. purpurea*	5	11 (6+5)	19 (8+11)	27 (11+16)	35 (14+21)	43 (17+26)	50 (20+30)
	T. vilosa	5	11 (7+4)	19 (10+9)	27 (13+14)	34 (15+19)	40 (18+22)	45 (20+25)
100	*T. purpurea*	7	15 (7+8)	24 (9+15)	35 (12+23)	46 (16+30)	55 (20+35)	63 (23+40)
	T. vilosa	4	13 (6+7)	21 (9+12)	29 (10+19)	35 (12+23)	41 (14+27)	45 (15+30)
500	*T. purpurea*	5	12 (7+5)	18 (9+9)	27 (12+15)	39 (15+24)	47 (18+29)	55 (20+35)
	T. vilosa	3	7 (5+2)	9 (6+3)	13 (8+5)	18 (9+9)	23 (10+13)	27 (10+17)

that ascorbic acid stimulates germination and early growth. However, in the present case there was no effect of ascorbic acid pretreatment on the percentage of seed germination but the early growth was enhanced. Chinoy *et al.* (1957) working on *Trigonella foenum-graecum* and *Brassica chinensis* have claimed that treatment of growing points with ascorbic acid stimulates the subsequent growth. Emmerich (1941) failed to find any effect of ascorbic acid pretreatment. In case of Orchid seeds also there was no effect ofasc orbic acid treatment (Noggle and Wynd, 1943; Henriksson, 1951).

Bonner and Bonner (1938), working on pea, have reported stimulatory effects of ascorbic acid for those varieties which synthesize less ascorbic acid in them, while varieties synthesizing more ascorbic acid are uninfluenced by added ascorbic acid. *T. purpurea* contained 38.5 mg of ascorbic acid per 100 gm of seedling while *T. vilosa* has only 17.5 mg ascorbic acid per 100 gm of fresh seedlings. So *T. purpurea* synthesizes more ascorbic acid and *T. vilosa* less, but both the species showed better growth irrespective of the concentration of the ascorbic acid in them. On the basis of our experiments there appears to be no relationship between ascorbic acid synthesis and added ascorbic acid on growth of the seedlings.

IV—Acknowledgements

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V—Summary

Experimental investigations into any possible relationship between ascorbic acid and water uptake and growth, and between ascorbic acid synthesis and added ascorbic acid and growth of the seedlings of *Tephrosia purpurea* and *T. vilosa* revealed that there was no effect of ascorbic acid pretreatment on the percentage of seed germination but the early growth was enhanced. It was also noted that although *T. purpurea* synthesizes more ascorbic acid than *T. vilosa*, yet both the species showed better growth irrespective of the concentration of ascorbic acid in them. Apparently there is no relationship between ascordic acid synthesis and added ascorbic acid and growth of the seedlings in the two species.

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EFFECT OF GROWTH RETARDANTS ON DROUGHT RESISTANCE OF CERTAIN ARID ZONE PLANTS

By

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ABSTRACT

The effect of three growth retardants, viz. CCC, Phosfon and B-995 on growth and drought resistance of certain crop plants as well as weeds of Indian Arid Zone was studied. Preliminary results indicated that, although the action of each growth retardant is specific, in general they inhibited seed germination, retarded extension growth, reduced the water requirement of certain plants, and increased the resistance of plants to drought. Since *Pennisetum* and other field crops are often adversely affected or even completely desiccated during prolonged drought in the middle of the rainy season, it would be most advantageous if, by virtue of treatment with growth retardants, the plants are able to evade drought because of their increased capacity for drought resistance. Thus, such treated plants would be better suited to survive under unfavourable water conditions. Results relating to the effect of growth retardants on drought resistance of plants in particular and potentialities of the substances in improvement of modern agriculture and horticulture have been discussed in detail taking into account a short review of the published literature.

DROUGHT RESISTANCE IN CROP PLANTS

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I—Introduction

The subject of water relations of plants is a vast one and it is not possible to cover even a few of its aspects in a restricted review of this type. An attempt will, therefore, be made to review briefly only the important features of the problem of drought resistance in plants with special reference to crop plants. For a more comprehensive study of this fascinating problem the reader may refer to reviews which have appeared from time to time (Maximov, 1929, 1939; Sizakyan, 1940; Zablouda, 1948; Levitt, 1951; Henkel, 1956, 1961; Iljin, 1957; Tumanov, 1940, 1951; Stocker *et al.*, 1943; Stocker, 1956, 1961; Chinoy, 1960; Kursanov, 1956; Petinov, 1966; Kozlowsky, 1964; Ruhland (Ed.) 1956).

Drought can be of two types : (i) atmospheric drought, and (ii) soil drought. In the former case high temperature and low humidity during critical phases of plant's life, such as the period of grain ripening, adversely affect its metabolism, grain filling processes and consequently its yield. In the case of soil drought the moisture of the soil may fall to a very low level thus preventing the plant from making good the loss of water through transpiration. In such a condition the plant is considered to have entered the state of 'permanent wilting' from which it cannot recover its turgor even during the cool hours of the night. Its turgor may be restored in the early stages of permanent wilting by removing the water stress of the soil. Temporary wilting on the other hand can be eliminated if the plant is placed in a humid atmosphere.

properties of the protoplasm, viz., permeability and hydrophily. He considered plants displaying special morphological and anatomical characteristics as belonging to a special class—xerophytes, not to be confused with plants showing resistance to drought by virtue of their special protoplasmic characteristics.

Stocker (1961) has recently tried to distinguish two categories of drought resistance : (i) Protoplasmic drought resistance, and (ii) Resistance due to special morphological and physiological characteristics.

II—Water Requirement of Plants

Briggs and Shantz (1913, 1914) defined 'water requirement' of a plant as the total amount of water required by it during its entire life cycle to produce one grain of dry matter. A number of workers have considered water requirement of a plant as an index of its drought resistance (Kisselbach, 1916, 1926; Briggs and Shantz, 1913, 1914; Bayles *et al.*, 1937; Leather, 1910; Livingston and Hawkins, 1915; Livingston, 1906, 1927; Paltridge and Mair, 1936). Maximov (1926, 1929) was, however, of the opinion that the water requirement of a plant was a variable character and not a constant entity, and therefore, its use as an index of drought resistance of a plant was of doubtful value.

Petinov and his co-workers (Petinov, 1954, 1955, 1966; Petinov and Prusakova, 1955; Petinov and Pavlov, 1955; Petinov and Kharanyan, 1956; Petinov and Lebedev, 1955) have studied the problem of water requirement of crop plants in relation to water economy in irrigation. These investigations have yielded very useful data and led to new systems of irrigation.

III—Method of Evaluating Drought Resistance of a Plant

The problem of evaluating the drought resistance, which is controlled by many internal and external factors, is a difficult one. It is on account of this reason that numerous attempts made to determine the degree of resistance by evaluating a single morphological or physiological characteristic have yielded results of limited value. Thus, for instance, attempts have been made to determine the resistance of a plant to drought by : (i) measuring the absorbing capacity of seeds (Skazkin, 1936); (ii) determining changes in the enzymic processes

during the period of drought (Sizakyan, 1938, 1940; Sizakyan and Kobaikova, 1947); (iii) determining the germination of seeds in salt solutions of increasing concentration (Sergeev, 1937; Sergeev and Lebedev, 1937); (iv) noting the rates of germination and seedling growth under conditions of water stress (Semakin, 1937; Shakti Gupta, 1957); (v) measuring the absorption of water vapour by seeds (Semakin, 1937); and (vi) determining the electromotive force in germinating seeds (Niznikov, 1940).

All the above mentioned methods are based on the tacit assumption that the capacity of a plant to resist drought remains unaltered during the juvenile as well as the adult phases which is far from being the case. The capacity of a plant to endure wilting changes considerably with the age of the plant (Stefanovskii and Guscin, 1937; Sokolenko, 1939; Fuchs and Rosentiel 1939-40; Zablouda, 1938, 1940, 1948; Skazkin, 1938, 1939, 1939a, 1939b, 1941; Konovalov, 1938; Chinoy, 1947a, 1960, 1961, 1961a, 1962, 1962a).

Attempts have also been made to determine the drought resistance of plants by subjecting them in the seedling stage to the effect of a current of hot air in specially designed chambers (Paltridge and Mair, 1936; Hunter *et al.*, 1936; Kenway and Peto, 1939; Aamodt, 1935; Shirley, 1934; Dexter, 1942, Platt and Darroch, 1942; Mueller and Weaver, 1942; Carroll, 1943). Size and depth of the root system of plants have also been considered as criteria for measuring their drought resistance (Cannon, 1911; Evans, 1937; Haber, 1938; Conrad and Veihmeyer, 1929). Haber (1938) and Pavlov (1930) have also tried to correlate the number and size of stomata and vascular bundles as well as osmotic pressure with drought resistance. Photosynthetic activity and growth have also been used as indices of drought resistance of a plant by a number of workers (Medvedev, 1937; Asana and Mani, 1950, 1955; Ashby and May, 1941; Stocker, 1961).

All the above mentioned methods have given results of limited value because in none of them the interaction of various internal and external factors which influence drought resistance at different stages of growth and development of a plant were studied.

Tumanov's method of permanent wilting was based upon Maximov's (1929) concept of drought resistance in plants already referred to in this review. This method essentially determined the survival value of plants under water stress and did not throw any light on the rate of its

revival after undergoing wilting. Ashby and May (1941) attempted to determine varietal differences in drought resistance of two oat varieties—Algerian and Fulghan. During the period of drought treatment (which was given simultaneously to the two varieties and not at comparable growth stages in each case) they found varietal differences in stem elongation and concluded that the variety which showed quicker stem elongation during the recovery period was more drought resistant than the other. As the two varieties of oats used by Ashby and May differed in their time of flowering the above conclusion cannot be considered as valid because irrespective of the creation of water stress or not the earlier flowering variety would always show faster stem elongation than the later flowering one. Such correlations between flowering and stem elongation have been established in our laboratory by Sirohi (1956) for a large number of oat varieties.

Direct agrophysiological experiments undertaken to determine growth, development and yielding capacity of different species and varieties of plants grown in the field both under irrigation as well as 'dry' condition have so far yielded the most reliable data regarding the ability of plant to endure drought (Zablouda, 1940; Saks, 1939, 1941; Ersov, 1939; Chinoy, 1947). Such studies on growth and yield behaviour of 260 wheat varieties were carried out by the present writer for a number of years from 1941 to 1947 (Chinoy, 1947, 1947a, 1949, 1950). Highly significant inverse correlations were obtained between grain yield and mean maximum temperature of the ripening period, as well as between 1000 kernel weight and mean maximum temperature of the ripening period. Experiments with wheat varieties belonging to different flowering classes which were subjected to various combinations of vernalization and photoperiodic treatments, showed that a synchronization of flowering was brought about in them. This also resulted in a shift of the ripening periods of early and late varieties in either a low or a high temperature range thus affecting beneficially or adversely, as the case may be, their 1000 kernel weight and yield (Chinoy, 1949a). Experiments on the ontogeny of the wheat grain have also clearly demonstrated the strong influence of the temperature of the ripening period on kernel growth in the plains of India as well as under vernalization and photoperiodic treatments (Chinoy and Sharma, 1957, 1958; Sirohi, 1956; Grag, 1960; Mansuri, 1965).

On the basis of the above mentioned studies experiments were

undertaken by the present writer to determine the resistance of wheat and barley varieties to wilting by using a modified Tumanov's method of permanent wilting depending not only upon the survival of plants after wilting, but also on the determination of their growth and yield responses (Chinoy, 1960, 1961, 1961a, 1962, 1962a, 1964; 1964-67; Chinoy, Jani and John, 1966). Drought intensity was determined in accordance with the formula (Chinoy, 1960) :

$$I = K \frac{t}{m}$$

where I is the drought intensity, m is the mean per cent soil moisture during the period of wilting, t is the mean temperature during the same period and K is a constant (number of days in the wilting period).

These experiments showed that wilting at the tiller initiation stage not only did not adversely affect the growth and yield of wheat but to a certain extent enhanced them more especially in early varieties. Wilting treatment at the shooting and the flowering stages on the other hand lowered the yield of grain and 1000 kernel weight. In both the cases there was a progressively greater reduction in yield and 1000 kernel weight with increasing lateness in flowering of varieties. This progressively increasing reduction in yield was ascribed to the prevailing higher temperature during the ripening period of late flowering varieties. Temperature of the drought period had also a profound effect on survival value as on growth and yield of plants after recovery from wilting.

Synchronization of growth and developmental stages in early and late flowering varieties brought about by subjecting them to various combinations of vernalization and photoperiodic treatments resulted in the elimination, to a considerable extent, of differences in their response to wilting. In other words the response of all varieties to drought treatment at any comparable growth stage was similar (unpublished data; also see Chinoy, 1964-67).

IV—PRE-SOWING HARDENING TREATMENT

Tumanov showed that repeated wilting resulted in a "hardening" of the plant tissue analogous to that observed at low temperature. On the basis of this observation various pre-sowing hardening treatments

have been evolved (Henkel and Kolotova, 1939; Henkel, 1939, 1956; Repin and Tiskov, 1940; Smirnova, 1939; Semakin, 1938; Isip, 1940, Chinoy, 1942, 1947a, 1964-67, 1967; Shakti Gupta, 1957; Nanda, Chinoy and Shakti Gupta, 1959). The method essentially consists of pretreating seeds with a solution of a salt or a growth regulator and drying them. This pretreatment is repeated three times and then seeds are sown in the usual manner. Recently the reviewer has developed a method of pretreatment of crop seeds with a solution of ascorbic acid (25-50 mg/l) which has given an increase of 20-30% in grain yield under field conditions (Chinoy, 1964-67, 1967). Results indicate that this pretreatment brings about some changes in the lyophilic colloids of seeds, enabling them to imbibe water even when there is water stress. There is enhanced hydrolytic activity of amylase in pretreated seeds. This is confirmed by a steeper fall in starch content of pretreated seeds with a concomitant increase in them of soluble carbohydrates especially sucrose. Rise in the sugar content is very conducive to the synthesis of ascorbic acid as shown earlier (Chinoy, 1962, 1964-1967; Chinoy *et al.*, 1965, 1967). It is worthy of note here that ascorbic acid plays an important role in imparting resistance to the plant against desiccation which might lead to the disorganization of the enzymatic mechanism (Chinoy, 1964-67; Stocker, 1956, 1961; Solomon, 1955; Startseva, 1963; Shcherbakov, 1963).

The question of paramount importance from the theoretical point of view as well at that of crop production is whether the varietal differences in drought resistance observed by many workers are due to real genetic differences in the properties of protoplasmic colloids, sugars, osmotic value of the cell sap, or the morphophysiological characters of the plant, or merely due to differences in environmental factors like temperature, humidity, light, etc., at the time of wilting treatment given to the plant as well as during some of the important stages of the plant life such as microsporogenesis, fertilization, development of the grain and others.

Recently Levitt (1962) has formulated the sulfhydryl-disulphide hypothesis for explaining frost resistance in plants in which it is proposed that injury is due to an unfolding and therefore a denaturation of protoplasmic proteins resulting from the formation of intermolecular -SS- bonds induced by the close approach of the protein interchange. Gaff (1966) has shown that this hypothesis can be applied

equally well in the case of drought resistance.

Stocker and his associates (Stocker, 1961) have tried to study changes in the protoplasmic structure by determining its viscosity and permeability. The viscosity of plants grown under constant dry conditions was found to be higher than that of plants grown under normal watering.

These workers could identify two phases during the time course of changes in the viscosity, (i) a reaction phase; and (ii) a restitution phase. During the first phase the viscosity was reduced to one-half its original level, thereby showing that loosening of the protoplasmic structure had occurred. When the moisture of the soil had reached 22 per cent of the field capacity the viscosity increased thus indicating that the protoplasm was reverting back to a firmer bonding. This was named as a "restitution phase". With a rising tendency in viscosity its value reached 3½ times the original value after nine days. This was called the state of increased drought resistance known as hardiness. With the restoration of soil mositure the viscosity came down to its original value on the eleventh day, the so-called "normalization phase".

Reaction and restitution phases were also observed during the measurement of permeability. Permeability increased for water, urea and glycerine during the reaction period. On the other hand the permeability for the first two substances decreased and for glycerine it increased during the restitution phase, thus indicating that it was connected with lipoid solubility.

On the basis of the foregoing these investigators have tried to explain the changes occurring in the protoplasm during the reaction and restitution phases as follows : The loss of water during reaction phase causes the shrinking of hydrophilic groups of the protein molecules leading to mechanical tensions and the exposure of bonds. As a consequence the bonds are broken and tearing and loosening of the structure of the protoplasm takes place. The protoplasm does not merely return to the normal state during the restitution phase but there are quantitative and qualitative changes in its protein-lipoid system.

mental stages on growth and yield of different Indian and American varieties of barley tried so far appears to be similar to that obtained in the case of wheat.

Seedlings at various stages of germination were desiccated for 5 and 10 days respectively and then revived. Determinations of various enzymes and other metabolites were carried out for embryo axis and endosperm separately before and after desiccation as well as after revival.

The longer desiccation perid depresses catalase activity. However, on revival it increases to such an extent that it surpasses that of undesiccated embryo axes. Amylase and lipase activities on the other hand are appreciably enhanced in the embryo axes during desiccation. Even after revival there is higher amylase activity, whereas there is a fall in lipase activity. There is no starch in the embryo axis. The endosperm of desiccated seedlings lose their starch much more rapidly than that of undesiccated ones. On the other hand there is an appreciable enhancement in reducing sugar content of desiccated embryo axes as well as endosperm. Sulphydryl content of the embryo axis is lowered during desiccation; but on revival the loss in—SH—content is more than made good. Concentration of free ascorbic acid as well as its utilization increase during 10-day desiccation compared to those in undesiccated embryo axis. On revival, however, the AA content registers a fall. The concentration of ascorbigen (bound ascorbic acid) is the highest in embryo axis revived after 10-day's desiccation.

During the adult growth period of the plant, also the effect of wilting on various metabolites of the leaf was determind before and during the period of wilting as well as after revival. In most cases leaves of wilted plants contained greater amount of reducing sugar compared to that in unwilted plants; whereas the reverse was the case with non-reducing sugar. The RNA content of plants receiving wilting treatment at the flowering stage was significantly higher than that of plants wilted during the shooting stage. The leaves of wilted plants generally contained more RNA in comparison to that of unwilted plants as well as that of plants which had revived after wilting. DNA content of plants wilted at the shooting stage was appreciably higher than that of plants receiving wilting treatment at the flowering stage. Wilted leaves showed an enhanced DNA content compared to that in the unwilted ones. Under continuous water stress —SH— content of leaves registered

a decline in comparison to that of fully watered series. Wilting of leaves at different stages of growth also depressed the —SH— content.

Leaves of wilted plants grown under long-day condition contain greater amount of free ascorbic acid and a lower concentration of ascorbigen in comparison with the leaves of plants grown under normal-day condition. Further the utilization of ascorbic acid in wilted leaves of long-day plants was slower than in corresponding leaves of unwilted plants. The reverse was the case under normal-day condition.

Earlier it was shown that alternate soaking and drying of seed brought about an acceleration in the flowering of nine varieties of Indian wheat (Chinoy, 1942). On the basis of this acceleration it was postulated (in 1942) that a separate developmental phase existed which was termed as the "drought phase". Such an accelaration in the developmental process of various crop plants has been observed from time to time (Chinoy, 1964-67, 1967; Chinoy *et al.*, 1966; Acharya, 1968). Further it may be noted that where the plants were revived after subjecting them to wilting treatment before or at the stage of tiller initiation there was invariably a significant increase in tiller and dry matter production, as well as in grain yield. Flowering was also accelerated to some extent. This beneficial effect on growth, development and yield produced during the period of revival after the plants had undergone "permanent wilting" for a number of days has been confirmed again and again for a number of crop plants during the last 27 years (Chinoy, 1942, 1947, 1960, 1961, 1961a, 1962, 1962a, 1964; Chinoy *et al.*, 1966; Acharya, 1968). It would, however, be well to point out here the fact that such an enhancement in growth and yield as well as earliness in flowering were brought about only in plants which were placed under "permanent wilting" during the juvenile stage or at the tiller initiation stage for a few days and then restored to normal water condition. In the case of plants placed under continuous water stress (7-10% soil moisture) there was appreciable reduction in growth and yield with slight earliness in flowering (Chinoy, 1964-67). Similarly wilting at the shooting and the flowering stages caused significant reduction in growth and yield of plants.

bakov, 1963; Chinoy, 1964-67; Chinoy *et al.*, 1968), also taking into consideration the ascorbic acid concentration of embryo axis and plants raised from seed which were pretreated by alternatively soaking and drying them in solutions of various growth regulators including ascorbic acid (Chinoy, 1964-67, 1967; Patel, 1967; Acharya, 1968; Henkel, 1961; Zemlyanukhin, 1964) and further considering the ascorbic acid—nucleic acid—protein metabolism concept of growth and development of plants put forward earlier (Chinoy, 1962, 1964, 1967; Chinoy and Mansuri, 1966), one is led to the conclusion that ascorbic acid plays a paramount role in providing protection to the plant during drought by creating a suitable redox environment for anabolic activities.

Over and above that a wilting period of short duration during the early stage of a plant's life stimulates the participation of ascorbic acid in synthetic processes as an electron donor during the period of recovery, most probably by the accelerated production of free radicals of ascorbic acid and also by stimulating the formation of a charge transfer complex between ascorbic acid and macromolecules. Enhanced growth and accelerated flowering obtained in the case of plants undergoing wilting during the tiller initiation stage are the resultants of the activation of metabolism as stated above.

In conclusion, therefore, it can be said that for the proper elucidation of the complex problem of drought resistance, both from the theoretical as well as practical standpoints, it would be not only necessary to undertake comprehensive experiments to study interactions of internal and external factors of resistance at different growth and developmental stages, but also to elucidate the complex of metabolic events and energy transfer systems underlying growth, development and yield of a plant.

V—SUMMARY

The subject of water relations of plants is so vast that even a few of its aspects cannot be adequately dealt with in a restricted review of this type. Therefore a few important features of the problem of drought resistance are dealt with here.

Both atmospheric drought and soil drought are conditioned by several internal and external factors which are interdependent in their action; and therefore the complexity of the problem can only be

resolved by carrying out comprehensive experiments involving interactions of several factors. It is for this reason that attempts to evaluate drought resistance of plants by measuring a single morphological or physiological characteristic such as absorbing capacity and enzymic activity of seedlings, rate of germination, electromotive force of seeds as well as depth of the root system, number and size of stomata and vascular bundles of adult plants have yielded results of limited value. Direct agro-physiological tests involving a complete analysis of growth and yield characters of a plant have so far yielded the most reliable data. Experiments have also been performed to determine the resistance of plants to 'permanent wilting' by determing the degree of survival as well as by studying the revival in terms of growth and development. In this also incomplete and one-sided studies have failed to produce results of real value. Only when a comprehensive study of different growth, development and yield characters was made in relation to environmental factors reliable information regarding the degree of resistance to drought could be obtained. Maximov considered two characteristics, viz. hydrophily and permeability of the protoplasm as the main factors of resistance. Levitt is of the view that injury is due to denaturing of protoplasmic proteins resulting from the formation of intermolecular -SS- bonds induced by the close approach of the protein chains.

Work in the writer's laboratory has shown that wilting during the juvenile as well as tiller initiation stages followed by restoration of adequate moisture level enhances growth, hastens flowering and increases yield. On the other hand, drought treatment at the shooting and the flowering stages, adversely affects these characteristics. Free ascorbic acid concentration rises during desiccation at the expense of ascorbigen (bound ascorbic acid). After the termination of the drought the concentration of free ascorbic acid declines and that of the bound one (ascorbigen) rises. On the basis of the foregoing as well as other data it has been suggested that over and above affording protection to enzymic and other metabolic processes from disruption during drought ascorbic acid accelerates these processes during the period of revival by accelerating the production of its own free radical and also by complexing with macromolecules to produce a charge transfer complex, thereby supplying electronic energy for the synthesis of the constituents of the cell at enhanced rates.

In conclusion the need for carrying out comprehensive experiments involving interactions of internal and external factors of resistance as well as a study of metabolic events and energy transfer systems is stressed to throw more light on this complex problem.

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PLANT-WATER RELATIONSHIPS UNDER ARID CONDITIONS OF WESTERN RAJASTHAN

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(With 2 Text-figures and 2 Tables)

I—Introduction

Plant life in general presupposes ample moisture. Under the arid or semi-arid conditions where natural supply of moisture is limiting, one feels naturally interested about the reactions of plants to water shortage, not only for its importance in plant life, but also for its direct impact on the productivity of the land. However, the subject of plant-water relationships under arid and semi-arid conditions is extremely complex and the diverse facets of this problem have been admirably presented in the Review of Research on this subject (1960) and the proceedings of the Madrid Symposium (1961), both published by the UNESCO. However, in Rajasthan we are particularly interested in the water relations of the plants which grow in its vast arid and semi arid tracts and, therefore, an attempt has been made here to outline the general information on this subject.

II—Water Loss from the Existing Perennials

The pattern of water loss of the plant species already existing in the desertic area gives us a primary clue about the nature of adjustments in their water relation which help them to overcome the rigours of water shortage. Moreover, appraisal of means by which the exploitation of the natural water resources of arid zone may be improved economically by modifying the structure of the plant cover, qualitatively as well as quantitatively, must be based essentially on a knowledge of the moisture turn-over of the existing or artificial forms of vegetation. Information, (Lahiri, 1964, 1965, 1966; Lahiri and Kumar, 1961) collected so far on the water turn-over behaviour of dune plants indicate that most of them transpire at a very high rate throughout

the year. For instance, in *Tecomella undulata* 9 to 10 gm of water was lost in a summer day per gm of fresh leaf tissue. However, only during the winter, due to low dawn temperature and shorter day length, water loss was reduced to about half. But the high rate of transpiration during the noon hours was more or less similar in both the seasons. There are, again, differences in the transpiration rates of different species. In plants like *Salvadora oleoides*, rather low rates are encountered which rarely exceed 500 mg/gm/hr, whereas, in certain other plants like *Aerva persica* transpiration during the afternoon may range between 1200-1500 mg/gm/hr. In any case, evidence collected so far indicate that the existing perennial vegetation of this area does not economise in their water turn-over. This is possible because in most cases they have very deep root system which enables them to tap water from deep moist soil layers. In one case it was found that a two feet high *A. persica* plant had a thick root system (2½" circumference) even at a depth of about 20 feet indicating root ramifications upto great depths.

Root excavation of *Prosopis cineraria* was undertaken by the late Prof. B.E. Nikolaevitch, UNESCO expert to this Institute, who found that even at 8-10 metres roots with thick secondary growth were going further down. These roots penetrated the kankar layer in the course of their growth. It is possible that this tree, which abounds in the sandy plains of western Rajasthan, behaves in certain regions like a "Phreotophyte" or "well plant" of Meinzer (1923) which habitually obtains its water supply from the zone of saturation either directly or through the capillary fringe and thus the perennial and secure supply of ground water makes it independent of the moisture regime of the upper strata of soil. Another phreotophyte of this area is *Prosopis juliflora*. Its roots have been reported to penetrate 60 ft below surface in Arizona (Kearney and Peebles, 1951). Extensive studies on phreotophytes have been conducted and an excellent review on the subject has been presented by Robinson (1958).

The ground water used by most phreotophytes has a low beneficial use so far as man is concerned and, therefore, Thomas (1951) has suggested the general term "consumptive waste" to denote the water returned to the atmosphere by these plants. Studies on the water loss of *Prosopis spicigera* tree community, consisti[illegible] of about 5[illegible]s, indicated that the annual water turnover is appr[illegible]ly 22[illegible]er hectare

(Lahiri and Kumar, 1967). Studies on the water balance of this community indicated that fluctuations of moisture tension in the upper layers of soil have hardly any effect on the internal moisture balance of this tree (Lahiri, 1965). During the summer months of May and June, when the soil water tension is often above 15 atm even upto a depth of 100 cm, the relative turgidity of its leaves varied only between 72.0 to 88.0 per cent. Further studies on water relation revealed its capacity also to absorb moisture through its aerial organs (Bhatt and Lahiri, 1964).

In U.S.A. consumptive waste of water by such plants in the arid and semi-arid West is considerable and therefore the importance of salvage is being considered where the demand for water is on the increase. Robinson (1958) has suggested that the salvage may be affected in two ways : Lowering the water table beyond the reach of phreotophytes by pumping or drainage and subsequently using it economically; and by substituting plants of high economic value. In western Rajasthan this problem also requires attention, keeping in view that not all phreotophytes are unproductive since they provide wind break, fuel, fodder, and also help in erosion control.

III—Adjustments Water Use at the Seedling Stage of Desert Perennials

Going back to the basic issue of plant water relationship, one feels interested to know about the moisture adjustments of the trees of this area at their seedling stage when the root system is limited. Investigations on the seedlings of *Tecomella undulata* indicated that fluctuations of soil moisture brought about by different levels and intervals of watering do not markedly influence the transpiration rate per unit area of leaf but the moisture economy is brought about by the reduction of total transpiring surface, as well as, by the reduction in the area of individual leaves (Lahiri and Kharabanda, 1966a). This adaptive mechanism may also be operative in the nature. In a drought cycle the reactions of the seedlings seem to be more or less identical to those of shallow-rooted plants.

IV—Reactions of Crops to Water Stress at Different Stages of Development

Unlike the deep-rooted plants, water relations of shallow-rooted plants, particularly of crops, are far more complex since they solely

depend on the moisture available in upper soil layers, i.e. largely the rainfall. In this context we may bear in mind that only the quantum of rainfall is not important but also its distribution. Since the resistance to water shortage is not a static feature but intimately related to the dynamics of development (Henkel, 1961), study of the effects of phasic drought on plants has a great significance. Investigations (Lahiri and Kharabanda, 1966) carried out on *P. typhoides* indicated that in general susceptibility to drought increases with the age of the plant, although, magnitude of responses alters in different phases with respect to different characters under consideration. It was further observed that water stress at the onset of reporoductive phase has the maximum adverse effect on the yield. Relatively higher moisture content in the older plants under drought conditions and greater vulnerability to moisture stress at those stages lead to the conjecture that in older plants small changes in tissue hydrature may bring large changes in metabolism. Subsequent studies (Lahiri and Kumar, 1966) further confirmed that drought effects are closely related to the senescence in bulrush millet. It could be demonstrated that drought effects may be reversed in young plants and this reversion mechanism becomes weaker with age. It has also been observed that the moisture stress decreases the yield but the grains which are formed are far more rich in nitrogen and proteins as compared to the plants growing under favourable soil moisture condition. Thus in desertic Rajasthan agricultural production, as such, may be low but there is no deterioration of the quality.

V—CONSUMPTIVE USE OF MOISTURE BY CROPS

It is of interest to know the extent of consumptive use of moisture by the crops of this area. It is to be noted that the consumptive use of moisture may be extremely variable since it depends on soil moisture supply, apart from certain other factors like temperature, humidity, wind movement, etc. (Makkink and van Humst, 1956; Prashar and Singh, 1963). Nevertheless, it may still serve as a useful index to compare the varieties and species under identical set of conditions. In experiments conducted under field conditions at Jodhpur during two consecutive years, 1964 and 1965, a general idea of consumptive use of different varieties of legumes has been obtained. From the Table 1 it may be observed that differences in rainfall have brought

about certain differences in the consumptive use in two years. Although the differences between the varieties were not large but the one having the highest value, was same in both the years. Similarly, for Bajra varieties RSK and RJS the consumptive use *has been found* to be around 180 mm and 176 mm respectively. Consumptive use is usually low in the seedling stage but increases progressively upto the reproductive phase which is followed by a decline.

Table 1.—Consumptive use of different varieties of legumes during two consecutive years

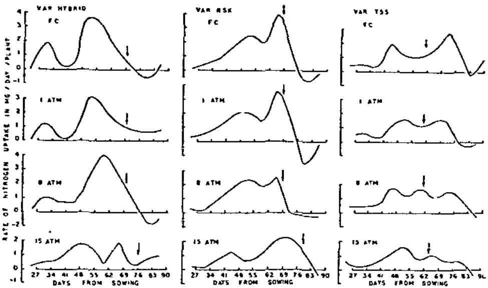
Species and varieties	1964		1965	
	Consumptive use in mm	Rainfall during growing period	Consumptive use in mm	Rainfall during growing period
C tetragonoloba (Guar)				
Var Local	97		70	
Var. I.C. 5495	110		100	
Var. Phalsana	95		69	
P. aconitifolius (Moth)				
Var. 4.I (57)	106	273	83	235
Var. Local	113		104	
Var. B 14.1	93		84	
P. aureus (Moong)				
Var. T 156	110		104	
Var Local	127		107	
Var. RS4	119		105	

The transpiration ratio or the water requirement of Bajra under our conditions is around 420. In the initial stages transpiration ratio remains high when the dry matter production is low. During the vegetative period increase in dry matter production lowers the transpiration ratio which increases again to high values at the end when the dry matter production ceases.

moisture usage early in the season and thus less moisture is available to plants at the reproductive phase which adversely affects the yield. In an experiment conducted at Central Arid Zone Research Institute, Jodhpur, during 1966 (190.2 mm rainfall during growing period) it was observed that in Bajra fields only about 40 per cent available moisture remained at earing stage which decreased further at flowering and fruiting. It is envisaged that fertilizer induced vegetative growth and consequent larger depletion of soil moisture would subject the plants to high stresses at the reproductive phase causing a decrease in production. But, the situation may be completely different if adequate nutrition induces optimum plant vigour as a drought evasive measure and better root growth for efficient moisture absorption from a larger area. Investigations on these problems remain under way.

VII—RELATIONSHIPS BETWEEN WATER UPTAKE AND NUTRIENT UPTAKE

In this relation the dependence of nutrient uptake on soil moisture condition is the central issue. However, experimental observations on this subject are rather equivocal. Hewthorne (1956) has listed nine papers reporting that the P uptake was unaffected within wide limits of soil moisture contents, and twelve papers reporting that the P uptake is decreased with decreasing soil moisture. Our unpublished data on the nitrogen uptake behaviour of Bajra varieties under different moisture regimes indicated that plants grown under low soil moisture conditions contain much higher nitrogen per unit of tissue weight in comparison with those growing under higher moisture regime. However, poor vegetative growth (associated with lower yield) under low moisture conditions decrease the dry weight of the plant and thus lower nitrogen content per plant. Data presented in Table 2 elucidate this point. Influence of soil moisture status on the rate of uptake of nitrogen has also been studied. From the Fig. 1 it may be observed that bajra var. Hybrid, RSK and T55 have double peaks indicating greater demand of nitrogen at the tillering and earing stages. It may be noted further that the intake rates at the field capacity, and at field capacity to 1 and 8 atm, were more or less comparable but it decreased only at the 15 atm regime.



Text-fig. 1. Time course of changes in N uptake rates of *P. typhoides* var. Hybrid I, RSK and T 55 under different soil moisture regimes.

Table 2.—Nitrogen content expressed as percentage of dry tissue weight and as mg/plant in Bajra var RSK, T 55 and Hybrid I (Age of plant 55 days)

Var	Control at F.C. (1/3 atm)		Plant watered to F C. when the soil moisture decreased to indicated tension					
			1.0 Atm		8 Atm		15 Atm	
	N %	N (mg/plant)	N %	N (mg plant)	N %	N (mg/plant)	N %	N (mg/plant)
RSK	1.2943	64.4511	1.2420	43 2216	1.4685	46 9921	1.9743	26 0607
T 55	1 2050	38.0780	1.3485	37.7608	1 4567	35 9804	1.5939	32.8343
HBI	1.3000	51.7400	1.3671	44.1573	1.4533	39.6750	2.0720	37 5032

VIII—EFFECTS OF WATER DEPRIVATION ON NITROGEN METABOLISM

The basic problem of relative drought resistance of plants, however, still remains unresolved. Although this character is often attributed to colloido-chemical properties of protoplasm, or in other words to qualities of protoplasmic proteins, our knowledge of this subject is fragmentary and inadequate. In general it has been observed (Stocker, 1960) that moisture stress leads to an accumulation of soluble nitrogenous compounds and thus a concept has been favoured for increased proteolysis. Investigations on the impact of water deprivation on the nitrogen

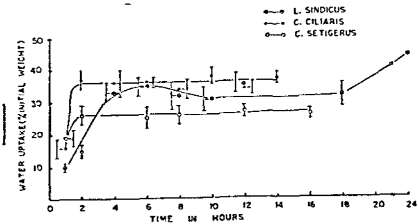
metabolism of *P. typhoides* indicated that in the initial stages of tissue dehydration increased accumulation of soluble nitrogen content was possibly due to decrease in protein synthesis (Lahiri and Singh, 1968). In the wilted plants protein degradation was also triggered off. Inhibition of protien synthesis resulted in increase in the level of amino acid nitrogen during the initial drying period while in the wilted plants hydrolysis of proteins could also be a contributing factor. Ammonia nitrogen does not occur in detectable quantity in the initial stages of drought but it increases in the wilted plants. Sharp decrease in the level of ammonia nitrogen on rewatering, with an associated increase in the level of amide nitrogen suggested quick incorporation of ammonia with organic acids as a measure against ammonia toxicity. Increase in the nitrate and nitrite nitrogen in the water deprived plants leads to the speculation that enzymes participating in nitrate reduction process may be affected by water shortage.

IX—Effects of Hyperthermia on Nitrogen Metabolism

Apart from drought, plants growing under arid conditions are often subjected to adverse supraoptimal temperatures. In dry habitat, heat rigour is frequently associated with moisture stress, where plants tend to evade over heating by increased transpiration. High transpiration rates of native vegetation, noted earlier in this paper, may be one of the means of heat regulation in these plants although quantitative data on this aspect are not available for our conditions. However, information has been collected on the metabolic alteration in *P. typhoides* under conditions of hyperthermia, where soil water stress was virtually absent (Lahiri and Singh, 1969). Hyperthermia triggered off proteolysis leading to increased accumulation of soluble nitrogenous substances. Degradation of proteins brought about an increase in the level of amino acid nitrogen. Ammonia nitrogen was found in detectable quantities after 12 and 24 hours' treatment at 48° ±1°C which caused injury to plants. It has been speculated that during the first six hours of heat treatment the level of ammonia was kept low by its increased neutralisation with organic acids as a detoxicating measure. Although amide production was enhanced beyond this period, fast catabolic processes and possible limitations of organic acid turn-over caused an increase in the ammonia level. The results suggest that increased organic acid production under hyperthermia may be a basis of heat har[illegible] in plants.

X—ROLE OF WATER IN THE GERMINATION REGULATING MECHANISM

Last but not of the least importance is the problem of initial establishment of plants. Germination of seeds under natural conditions, in arid tracts, is subjected to various adverse conditions and this has a serious impact on the subsequent stand of vegetation. Among the many factors which run counter to the natural propagation, meagre, as well as erratic rainfall and quick depletion of soil moisture are, of supreme importance. However, considerable information on the overall germination regulating mechanism of desert plants, particularly of native grasses and trees, has been collected in recent years (Lahiri and Kharabanda, 1961, 1963, 1963a and 1964; Lahiri and Kumar, 1966a; Lahiri and Gaur, 1969). These studies indicated that the differences in the size of seeds or their dimorphic nature has a significant impact on the subsequent stand. Moreover, it was found that the quick water uptake and speed of germination are the main determining factors for success of establishment. Therefore, it is necessary to establish water uptake curves for different seeds. Relative differences in water uptake rates and time taken to attain the equilibrium stage of water uptake for three grasses of this area have been illustrated in Fig. 2.



Text-fig 2. Water uptake in seeds of *L. sindicus*, *C. ciliaris* and *C. setigerus* at different hours after soaking.

It could be further demonstrated that water intake of endosperm and that of embryo are two distinct processes and effects of naturally occurring germination inhibitors like coumarine primarily affect the water

uptake by embryo. The glumes of grasses like *Cenchrus ciliaris, C. setigerus* and *Lasiurus sindicus* which may absorb water 60 to 100 percent of their weight, serve more as a hinderance than help in the germination of enclosed seeds because they contain inhibitors. Success of plant establishment remains uncertain till these inhibitors are washed away by showers. Occurrence of germination inhibitors in the leaf tissue of *P. juliflora* has also been reported (Sankhla *et al.*, 1965). Subsequent studies (Lahiri and Gaur, 1969) lead to the separation of one strong and one weak inhibitor from the leaf extract. Inhibitors contained in the leaf-litter inhibited the germination of different seeds to different extents. These being specific inhibitors, radicle emergence and root growth were restricted and thus affected the water intake of the young seedlings.

The foregoing account on some selected fields of plant-water relationship gives us a glimpse of the diversity and complexities of the problem. If we aim at a greater production from this area, where the returns are usually low due to the hazards of nature, intensive researches on plant and environment complex are necessary so that the problems of arid zone may be approached with greater confidence.

XI—SUMMARY

This paper deals with the different facets of the problem of plant-water relationships in western Rajasthan.

The unrestricted water loss throughout the year in many desert perennials may be ascribed to their deep root system. It is possible that under certain situations they may be tapping the ground water to meet their transpiration demands. At the seedling stage, however, under conditions of water shortage these plants economise in moisture use by reducing the surface area of leaves. This mechanism may also be operating in mature plants.

In shallow-rooted plants like *Pennisetum typhoides* susceptibility to drought changes at different phases of its growth vary and the maximum adverse effects are produced at the onset of reproductive phase. Although the grain yield decreases very much in the droughted plants, nitrogen and protein contents of grains increase under such conditions.

Consumptive uses of moisture of different varieties of legumes and bulrush millets indicate that amongst other factors rainfall varia-

tions may change the values in different years. Consumptive use is usually low in the seedling stage and it increases progressively upto the reproductive phase followed by a decline. At the earing stage only about 40 percent available moisture remained in the soil which suggested that high fertilizer treatments which induce rapid vegetative growth and greater consumptive use may further degrade the soil water status at the critical stage. Legumes like guar, moong and moth have a lower consumptive use than Bajra.

Plants growing under low soil moisture conditions showed greater nitrogen concentration in comparison with those raised under higher moisture conditions. However, low tissue weight of the former resulted in lower nitrogen content per plant. The rate of uptake of nitrogen in bulrush millet, which has a double peak, does not change with alterations in moisture regime except under extreme conditions, although, the position and height of peaks may vary.

Water deprivation leads to impediments in protein synthesis and at wilting protein degradation is also triggered off. Hyperthermia directly leads to hydrolysis of proteins. Under both these stresses capacity to produce more of organic acids to neutralise the ammonia produced under extreme conditions may be a metabolic index for resistance.

Amongst other factors, water uptake characteristics of seeds and occurrences of germination inhibitors have a significant impact on the establishment of desert plants.

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meaning thereby that when Famine reclines, its feet are in Pungal, belly in Bikaner, head in Merta, it sometimes visits Jodhpur but has its permanent abode in Jaisalmer.

Whatever be the causes of these famines, as a net result of these, the land is deprived of its plants either by the famine-stricken people or their half-starving and ever-hungry horned-heads. Food has ever been man's first quest since his very arrival. In the face of scarcities the hardiness and power of resistance of the native people of the desert areas has increased, since it has been observed that every year if there is abundant grazing the crops are poor; if the crops are good, the water supply in the tanks runs out before the next monsoon, and, if both water and grain are plentiful the grazing is scarce for want of sustained drizzles during the month of '*Sawan*' or the months of July-August. The year when all those adverse conditions are in collusion, the purchasing power of the otherwise resourceless and chronically poor inhabitants, falls much too low and the only alternative left with them is to derive their sustenance from the scattered wild plants which thrive on the otherwise almost barren land. They collect the seeds, roots, tubers and bark of the hardy plants that are the only easily available eatables to these famine-stricken people. This is, however, not a new method of fighting food famines, since the ancient Indian saints and sages derived their sustenance solely from the wild plants of the forests.

The Famine Inquiry Commission in its final report of 1945 (p.24), has emphasized the great need for the supply of the supplementary foods, that is foods other than the main cereals. Moreover, in the wake of the famine of 1950 even the late Prime Minister Pandit Nehru had rightly said, "It is not a time to embark upon the dietary reform and to wean people away from their usual and habitual herbal and animal food stuff which do not affect their health adversely."

II—FAMINE FOODS

While preparing the Flora of the western Rajasthan Desert, I had the opportunity to visit the interior of these desert areas and while enjoying the hospitality of these poor people, many a time, I have collected firsthand information from these people about the emergency foods they are accustomed to use during scarcities. Having myself eaten some of the preparations of these wild plants, I naturally became inter-

ested in a detailed survey of the famine foods used in these desert districts.

There are many plants used as famine food in Rajasthan Desert. Some of them are of great importance from the standpoint of emergency foods; others are of minor value, being used only rarely when better famine foods are also not available. Undoubtedly, there still are a large number of plants of emergency value that are not quite recognized today though future study or experience will bring them to light. Although it is very difficult to prepare an exhaustive list of these edible food grains and other wild eatables used by natives in times of scarcities, in the following pages various emergency foods used by desert people are listed along with their local names.

1. *Prosopis cineraria* (Linn.) Macbride (= *Prosopis spicigera* Linn.), '*Khejri*' : Is undoubtedly an exceedingly generous blessing which nature has bestowed upon the Indian Desert. It is the most conspicuous plant since it is the only tree worth the name in most of the parts. It provides shelter and shade to the weary, sun-scorched traveller, and besides being eaten by the camel, goats and cattle, its leaves and shoots provide vegetables to the inhabitants.

The young pods called "*Sangri*" are used as vegetable and are consumed as such even during the years of 'plenty'. These are collected, boiled, dried and preserved. A considerable quantity of such '*Sangri*' are exported normally every year to the numerous parts of the country. The mature pods which contain a sweet pulp, on the other hand, are eaten as such. The bark of this tree has been eaten during the severe famines in 1899 and 1939. It is stripped off, dried and group with some other types of available coarse grain to make up the meagre meal contained in it and attain a more substantial value. Dr. G. King in 1869 wrote about the food value and utility of the bark of this species. "The bark of '*Khejra*' (wrongly identified as *Acacia lucophloea*)—a tree common in Rajpootana. Bread is made from the ground bark with or without the addition of flour. It has an astringent bitter taste and is far from palatable. On the principle of experimentum in corporevili, I made my sweeper fare on it for a day. The poor man suffered a good deal of griping and discomfort in consequence. I found this to be the usual experience for the first few days that either this or '*Mothee*' (*Cyperus* sps.) are eaten but ultimately the stomach gets accustomed to the nauseous food" (Pl. 2 a).

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5. *Lasiurus hirsutus* (Forsk.) Boiss. (= *Elyonurus hirsutus* (Vahl) Munro, the '*Sevan*' grass is one of the most valuable perennial fodder grasses of this region and often forms extensive pasture land. It is abundant in Jaisalmer, Phalodi and Bikaner districts. The seeds are collected, ground and mixed with '*Bajra*' flour, and baked into '*Sogra*' (Pl. 2 e).

6. . *Dactyloctenium sindicum* Boiss., the '*Tantia ghas*' which cover much of the harder ground in this region and is a good fodder for the cattle, has also been used as food by natives in times of scarcity. However, the grain which is consumed, has been reported to cause internal disorders (Pl. 2 f).

7. *Citrullus colocynthis* (Linn.) Schrad. (=*Colocynthis vulgaris* Schrad.), the '*Toos*' or '*Tumba*' *or* '*Tastumba*', a scabrou strailing perennial cucurbit, found on the sand-dunes and open plains throughout this region, is most abundant in Barmer and Jaisalmer districts. It forms large patches on loose sand. Its long branches radiate in all directions from the central rootstock. The seeds which have been chemically examined by Power and Moore (1910) are gathered, washed with salt water many times to remove the bitter principles (mostly contained in the attached pulp) or are buried with common salt in small dugonuts in the sand, kept covered there for few weeks, washed, dried, ground and used. '*Sogra*'or a rather hard-baked bread is made either solely of '*toos*' flour or mixed with '*Bajra*' flour. '*Kankara*', a delicious dish, mentioned earlier is prepared by mixing '*Toos*' seeds with '*Bhurat*' *Atta*. The entire seeds of '*Toos*' are mixed with the '*atta*' of '*Moth*' (*Phaseolus aconitifolius* Jacq.) and are prepared into thick '*chappaties*' (Pl. 2 g).

The gum obtained from the young plants of *'Khejra'* known as *'Bantaka'* is eaten by many classes of people during months of May-June, when it is available in plenty. The large plants, however, do not yield much gum.

2. *Cenchrus biflorus* Roxb. (= *C. catharticus* Del.), *'Bhurat'* is the queen of the cookery herbs of Jaisalmer. It has been in use there as a subsidiary food since times immemorial. Brought out by only a few early showers, it is one of the most abundant grasses of this region, found throughout the desert, and is collected in normal as well as deficit years. In times of famines and scarcity it is often plentiful when other plants cannot come up. The seeds of this grass, which are about the size of a pin's head, remain enclosed in a prickly husk (which causes a great deal of discomfort to both man and the animal since it sticks to the clothes of the former and the wool of the latter), are removed from the burs, though with great difficulty, are ground and baked into a thick, unlevened bread. It is regarded as the most nutritious of the famine foods. Even in normal years its fried *'Atta'* mixed with *'ghee'* and sugar is given to children for the improvement of their health. The seeds are regarded to have a high fat and protein contents and therefore it is believed that if taken continuously for a few months it results in the increase of weight and is good for muscle building. Even as a cereal too, people value it next to *'Bajra'*. *'Khankara'* — a delicious dish is prepared by mixing *Bhurat-Atta'* with the seeds of *'Toos'* — another famine food referred to elsewhere. To many classes of natives it is a sacred food, the use of which is permissible even on days of religious observance, prescribed by rituals followed in this region, when the consumption of all other cereals is strictly forbidden (Pl. 2 b).

3. *Cenchrus setigerus* Vahl, *'Dhaman'*. Less common than the last species during times of scarcities, is specially favoured wholesome by cattel. The seeds of this species have also been reported to be ground and used as food by people (Pl. 2 c).

4. *Calligonum polygonoides* Linn., the *'Phog'*, which is one of the most common bushes on bare sand-dunes, where it often forms pure associations, is another local plant used as famine food. Its buds called *'Lassan'* are used by the poor with the butter-milk called *'Chach'* and salt, in the months of February and March. when little else is available (Pl. 2 d).

15. *Tribulus terrestris* Linn., *'Kanti'*, is a prostrate branched annual herb, the small spiny fruit of which is said to have constituted the chief food of the people during the Madras Famine, Lisboa, 1886; Watt, 1890). The hard seeds are gathered, stored and reduced to powder and eaten after baking into a bread or the powder is mixed with the flour of Bajra. Since the plant comes up even after a few showers, the seeds are collected, stored and used, if so required, in the times of scarcity. Since they are hard and indigestible, they are not given preference if other digestible foods are available.

16. *Indigofera cordifolia* Heyne., *'Bakereya'*, is a much common plant of the waste places and fields. Its minute seeds which are somewhat unpleasent to taste, are made into cakes either alone or with some cheap cereals (Pl. 2k).

17. *Indigofera linifolia* Retz., *'Sidio bakereya'* or *'Bhur-Bhura'*, as it is called by the natives, is rich in nitrogen contents and like the previous species, the seeds of it are consumed after grounding and being them into bread.

18. *Tamarindus indica* Linn., *'Imli'*, handsome evergreen tree believed to be a native of Abyssinia and Central Africa, whence it came to India, is often planted at village *'Chohata'* (central places of the village) and wells. The seeds which consist of a dark reddish brown outer husk or testa and an inner cream-coloured kernel, eaten even in the ordinary times, are reduced to powder, and baked into breads. They are also roasted and eaten by the poor classes instead of betel nut and are much liked by village women. The pulp of the fruits is used as a routine food during ordinary times and the fruit is sold in the market.

19. *Acacia nilotica* subsp. *indica* (Benth). Brenan (= *A. arabica*), *'Banvalia'*, though not used very often, the seeds known as hilario are eaten roasted, or raw, in very acute times of scarcity. In the famine of 1904 even those seeds of this species which had been voided by goats that have eaten the pods of it, are reported to have been gathered, roasted and eaten. However they might have been cooked, these seeds have been found to be deliterious to health in the long run. The gum, which is highly nutritious, is used as a chewing article. The ground bark, mixed with the seeds of *Sesamum orientale*, has been used as food as reported by Watts.

20. *Capparis decidua* (Forsk.) Edgew. (= *C. aphylla* Roth). *'Ker'*, a straggling, thorny, leafless shrub, or a small tree, found throughout the

Elphistone "In the midst of so arid a country, the water-melon, the most juicy of the fruits, is found in profusion. It is really a subject of wonder to see melon of 3-4' in circumference growing in the dry sand of the desert. The natives assert that the large melon suffices to allay the thirst of a camel and a rider". The pulp of the water-melon is largely consumed, being eaten fresh, the seeds are dried and pounded into a flour and mixed with the flour of *Bajra*, cakes called '*Sogra*' are prepared from it. These small flat seeds when dried are said to taste like almonds. In normal years the fruits are available in such a plenty that much of these are thrown to the cattle (Pl. 2 i).

10. *Acacia jacquemontii* Benth., '*Boo banwali*', yields a small quantity of gum, although of inferior quality, which is used in the times of scarcity to pass some days when no other edibles are available.

11. *Acacia leucophloea* Willd., '*Arunja*', has been mentioned by King in Western Rajputana to have been used as famine food. The grey bark is ground and mixed with flour of Bajra in times of scarcity and eaten. The young pods and seeds, according to Brandis (1874), are used as vegetable. The plant is, however, not so plentiful in the area to be utilized to a great extent.

12. *Zizyphus nummularia* Wt. & Arn., '*Borti*', a thorny, tomentose bush, very common in dry open plains, flourishes well even in the years of scanty rainfall. The fruits which are globose, scarlet-red when fully ripe and less than 1 cm in diameter are gathered in the beginning of winter months, dried, ground and sieved. The powder so formed is eaten either alone or mixed with '*Gur*', sugar condiments or the flour of bajra. The stone of the fruit being very hard, is indigestible (Pl. 2 j).

13. *Zizyphus mauritiana* Lamk. (= *Z. jujuba* Lamk.), 'Bar-Bor', like the last species the sweet and somewhat acidic fruits of this species are also collected, dried and powdered or eaten as such. The fruits are somewhat larger being about 1.5 cm in diameter.

14. *Sorghum halepense* (Linn.) Pers. (= *Andropogen halephensis* Brot.), '*Baru*', is one of the best grasses which can withstand long drought and is, therefore, a good famine plant. Its power to withstand considerable salt in the soil also renders it available during times of scarcity. This species is usually given to cattle, although it has been reported that during the failure of monsoon when this plant matures, it is often attacked by a small black insect known as '*Valo*', if the cattle eat the '*Valo*' affected plants, the cattle die immediately.

bread, A little flour is sometimes mixed with it. The accompanying specimen of bread, I got from a man who, with his family, was making a dinner of it".

III—EMERGENCY FOOD FROM ANIMAL RESOURCES

Apart from the subsidiary foods obtained from local plants, in emergency the animal food is also appreciable. It has been estimated that more than 80% of the inhabitants of the desert district of Jaisalmer are Mohamedans, Rajputs, Meghwals, Bhambis and Bhils who are nonvegetarians. They all relish animal food. In addition to '*Shikar*' or shooting, lot of sheep and goats, particularly in the wake of famine, supply large quantity of meat. But of all the subsidiary foods of the animals origin, the desert locust (*Schistocerca gregaria* Forsk.), which serves as the most delicious food, is relished both in fresh and preserved state. These are collected, whenever available, in large quantities and for the '*Mussalmans*', living near the Pakistan border of Sindh and most of the '*Meghwals*' and '*Bhils*', it forms as important a food stuff as probably the fish in Bengal. They are chiefly stored and used during scarcity. It has been reported that the locust stored during 1950 in Jaisalmer alone was 100 mds—a quantity sufficient for a month's supply in that region (Anonymous, 1950).

Of the '*Shikar*' animals '*Tillore*' bird, which is found in abundance during winter season, is relished the most. Its flesh is fatty and very delicious.

Not only during famines, but even in normal times, there are thousands of people who live for months on camel-milk which does no harm to them and keeps them in extraordinary good health. The milk though poor in fats is rich in nitrogenous substances. It has a tallowy odour and is said to act as laxative to those unaccustomed to it.

Despite the fact that 'famine foods' are deficient in many dietary essentials, apart from proteins and calories, the fact remains that since no other plants or other foods are available in the interior of the desert due to many factors, people have to live on whatever they get from the natural resources around them. Therefore, when such chronic famines cast their shadows, the first step is to start the famine relief operations, as is rightly being done by the Government, and the second step is to supplement these natural diets, as a routine measure, by

region; bears red or pink berries. The unripe fruits are also pickled or used as vegetables and the flower-buds are cooked as potherb, and the honey from it is eaten by village boys.

21. *Salvadora oleoides* Decne., *'Jal'*, an evergreen shrub or a small tree; this species is found throughout the arid tracts particularly where the soil is slightly saline. The sweet edible fruits are very much liked even in normal times, but they are believed to produce tingling and small ulcers in the mouth if taken one by one; for this reason they are taken in handfuls. They are also dried and used when more palatable food is not available (Pl. 2 I).

22. *Achyranthes aspera* Linn., *'Andhi-jaro'*, an annual herb of the waysides and waste places; has been reported to be used during famines. In normal times, however, when the plants are available in plenty the seeds boiled in milk or *'chach'* or whey, have been regarded as a good tonic, if they are taken for about a month during the winter.

23. *Eleusine coracana* (Linn.) Gaertn., *'madua'*, is a rather staple food of lower and poorer classes of people; sown the earliest in its season, heavy crops of it are produced with little or no effort particularly when there is water scarcity. It is said to be very nutritious and *'Rabri'* prepared by boiling down its flour in diluted buttermilk *(Chach)*, is generally cooked in the evening and kept for use the next morning. The coarse pounded flour, boiled thick in water is also consumed as *'Ghat'* or *'Dalia'*.

Sesamum indicum Linn., *'Til'*. The refuse of the seeds of this species has also been reported to be used as a substitute food. In this connection King (1869) mentions "The refuse of the seeds of *S. orientale* (=*S. indicum*) remaining after the oil has been expressed, is not made into a bread, but is boiled with water and made into a soup. The specimen exhibited was brought from a *'Baniah'* in Jodhpur Bazar, who was selling it to an eager crowd, at the rate of seven seers for a company's rupee. In Marwar this substance is largely stored by *Baniahs* against seasons of scarcities. It keeps for many years without further deterioration then a darkening of colour".

Cyperus rotundus Linn. *'Mothee'* (mentioned by King (1869) as the roots of *Hymenochate grossa*) are the tubers of this and other species of *Cyperus*. According to King, "In the times of scarcity the roots are eagerly dug up for human food. The fibre and the dark cuticle being removed, the solid part of the root is dried, ground and made into

known as 'Johnson-grass' in New South Wales, has been reported to be poisonous to stock particularly when young or stunted since it is strongly cynogenetic (Hurst, 1942). Another plant *Tribulus terrestris* Linn., known locally as '*Kanti*' and used as famine food not only in Rajasthan but has been used even in the Madras Famine, has been shown to cause 'big-head' or '*geeldikop*' in sheep. The nitrate, detected in variable quantities in the plant, was converted into nitrite by the reducing enzymes which rapidly change the haemoglobin of the RBC to methemoglobin, resulting in the asphyxia of the affected animals (Webb, 1948). In New South Wales this plant has been reported to cause mortalities in hungry sheep and cattle with symptoms of HCN poisoning (Hurst, 1942). *Citrullus colocynthis* the '*Toos*' still another of the much used famine food, the dried pulp of which is official in the British pharmacopoeia codex, is a powerful hydragogue cathartic. Indigenous methods have, however, developed to remove the bitter or poisonous principles, since some of the pulp which contains these elements remains attached to the seeds. Yet another of the famine foods, *Citrullus lanatus*, the '*Matira*', has a wild from which is very bitter and probably poisonous (Webb, 1948). These are some of the many examples of plants which are known and found to contain toxic elements. Since there might be many more which might prove deleterious but reports about them have not come, it is imperative that all these plants should be analysed in detail to this effect. It is also believed that most of these plants contain less of salts and if eaten without being seasoned with a proper quantity of salt, may lead to the deterioration of the nutritive fluids of the human body, resulting ultimately in the production of various ailmentary troubles and other diseases. Remarkable developments have been made in the nutritional science these days and it is now well known that a diet which may be sufficient in quantity might be unsatisfactory in quality. We must therefore guard against the effects of malnutrition while avoiding undernutrition. More care is required when both malnutrition and undernutrition co-exist as is the case at present.

Besides the plants which are already being used, there are certain potential species wild in this region, but which have not been utilized as food here although they have been profitably used elsewhere; and as such we might also make use of them, of course, after proper analysis. *Balanites aegyptiaca* a member of Simaroubaceae, known as '*Hingotia*' in Rajasthan and 'Desert-date' elsewhere, occurs in dry regions of west

synthetic vitamins and vitamin concentrates in the form of tablets, capsules and pills. Mineral tablets may also be distributed free which will supply many essential minerals in assimilable form.

Famine-foods are certainly less nutritive and might even contain some of the undesirable elements and therefore they must first be rendered normal for human consumption. The various methods already in use differ in details for various plants, and even for the same species at different places. As a general rule, however, the seeds of most of these plants are ground and made into cakes either entirely of their own flour or they are mixed with the flour of Bajra, which is the staple food in this region and regarded as an inferior grain. Most of these are not easy to be digested. It is a common complaint that people who lived on these famine foods become lean and weak and suffered from the alimentary disorders. Since these foods have less nutritive value, large amount of them has to be consumed to satisfy the hunger, but all of which cannot be digested and assimilated. Moreover, most of these famine foods contain more of woody tissues, gummy and resinous substances and various extractive matters which are neither digestible nor nourishing. They might temporarily satisfy the hunger but their exclusive use for a prolonged period brings about decay and renders the constitution an easy victim to many ills. It has been reported (Anonymous, 1909) that some of these herbs which were used during the famine in 1897 and 1904 in Jaisalmer have been chemically analysed as early as 1904 and their moisture, protied, fats, oil, fibre and carbohydrate contents ascertained and their digestibility and calorie values have been obtained but the details thereof are, however, not known. It is, therefore, urged that all the wild grains and vegetable produce and barks which are consumed as famine foods be scientifically examined by qualified nutrition officers with reference to their chemical composition and calorie value since many a time the most closely related plants, say, the species of the same genus might have entirely opposite nutritive value. One species may be most delicious and might have nutritive value while the other may be poisonous and harmful. However, it is believed that if the seedling and the tender shoots of these plants and even the seeds of species having bitter taste, are properly boiled, they may be consumed with impunity.

Some of the species which have been used as emergency foods have been reported to be poisonous elsewhere although no such cases have been reported in Rajasthan Desert. For example *Sorghum helepense*, the '*Baru*',

as has been done by the *Citrullus lanatus*, *Tamarindus indica* and many others.

There is nothing intrinsically impracticable in my suggestion, but if well meaning critics sneer at these proposals treating them as utterly unpracticable and utopian, it may be suggested that the practical benefit to utilize, analyse and develop these famine foods, which have been utilized by the natives as a result of their experience extending over hundreds of years will be very helpful as an immediate step in a state of acute crisis when the news of deaths by starvation often appears and when hunger and despair are writ large on the faces of the famine hit people; and when these men, women, and children are driven, out of sheer despair, to wander the streets of cities in search of food and jobs. It is the duty of every citizen to put his might to arrest the pangs of hunger, for, as it is, the life of man is far more precious and important than anything else.

The conclusion is simple—the potential is here; we need but to study it and develop it further.

IV—SUMMARY

A survey has been made of all such emergency or famine foods as are used by natives, particularly by the poorer people of the Indian desert. It has been found that 23 plant species are utilised as famine foods and, depending upon the local availability, different species are used in different places. Some of the more common species are *Prosopis cineraria*, *Cenchrus biflorus*, *Calligonum polygonoides*, *Capparis decidua*, *Zizyphus numularia*, *Dactyloctenium sindicum*, *Tribulus terrestris*, *Lasiurus sindicus*, *Citrullus colocynthis* and *Citrullus lanatus*. The chemical composition and nutritional value of these emergency foods need to be determined in detail since some of the plants used, e.g. *Tribulus terrestris* and *Citrullus colycynthis*, are reported to be poisonous. The non-poisonous foods found to be deficient in vitamins or minerals could then be supplemented with synthetic preparations to correct the deficiencies.

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Africa where innundations occasionally moisten the ground. It is a valuable food and the fruits are sometimes used in making a kind of bread, or they are eaten in soup as by *Shwa Araba* (Irvine, 1948). In addition they provide an edible oil (over 40% of the seed). A pleasant drink known as 'Kango' in 'Mausa' is also prepared from its pulp. Similary an attractive beverage is prepared from the macerated fruits of the Jujube trees (*Zizyphus mauratiana*). *Citrullus lanatus*, already referred to above, has been used in W. Africa either raw or cooked in soup in various ways. Its seeds known as '*egusi*' are dried in the sun, the husks are removed and the kernels are then roasted and put into soup or used as an ingredient in a sauce. They are of good food value (roughly 45% fat and 34% protein), and the oil in them is suitable for cooking. Sometimes the kernels are fermented by the '*Yorubas*' of Nigeria to form a food or flavoring called '*ogiri*'. Another food is made from the roasted or pounded seeds which are wrapped in a leaf and boiled. Sometimes the seeds are fried with oil and red pepper added. *Coleus dysentricus* — the '*sudan potato*', regarded as the most suitable substitute for potato in hot climates, is widely grown in drier parts of Tropical Africa. *Dioscorea praehensis*, the bush or forest yam, the tubers of which are occasionally used as famine foods in west Arica, is best known as the parent of the cultivated white yam. *Dioscorea presussii*, while used mainly as famine food, the wild tubers are still used by hunters, but only after being thoroughly soaked and the liquid discarded to remove the poison contained in it. *Acanthosicyos horrida* Welw. & Hook., which survives on dry sand-dunes and emerges more boldly every time it is covered with sand, has edible fruits, of course when ripe; the seeds also contain a considerable amount of fats and are regarded as an excellent substitute for almonds. Species of *Echinocystis* which occurs wild in Arizona, have, tuberous roots, as large as a man's head. It is freely eaten by native Indians. *Cucumis humifructus* Steud., another interesting cucurbit which is geocarpic since the fruits remain buried in the deep fine sand, can also be a beneficial introduction. There are numerous other desert plants which can be introduced profitably in our region. No doubt a thorough understanding of their ecology, physiology and drought resistant capacity should be studied in detail before they are introduced on a large scale in this region. Such plants if introduced in large numbers, will in times to come naturaliez

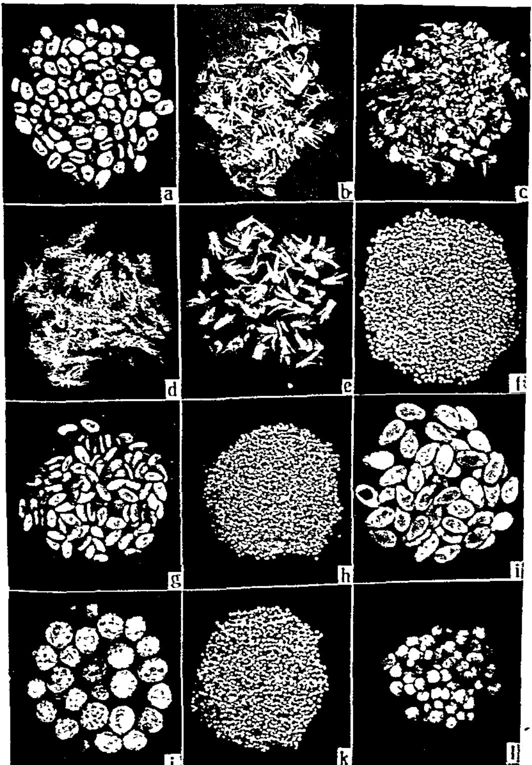
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Plate 2

a. Seeds of *Prosopis cineraria*
b. Burs of *Cenchrus biflorus*
c. Burs of *Cenchrus setigerus*
d. Fruits of *Calligonum polygonoides*
e. Burs of *Lasiurus hirsutus*
f. Seed grains of *Dactyloctenium sindicum*
g Seeds of *Citrullus colocynthis*
h. Seed grains of *Dactyloctenium aegyptium*
i Seeds of *Citrullus lanatus*
j Dry fruits of *Zizyphus nummularia*
k. Seeds of *Indigofera cordifolia*
l. Fruits of *Salvadora oleoides*

SECTION B

Animal Resources of Rajasthan

1. Faunal composition of Rajasthan
2. Animals useful to man
   - (a) Livestock (cattle, sheep, goat, camel)
   - (b) Fish and fisheries
   - (c) Hides, skins, bones, wool and their marketing
3. Animals harmful to man
   - (a) Rats and other rodents
   - (b) Grasshoppers, locusts and termites
   - (c) Other insects and animals
   - (d) Nematodes as plant parasites
4. Wild life of Rajasthan

Chairman Prof. S.D. Misra
Recorder Dr. P.D. Gupta

Chairman's Address

ANIMAL RESOURCES OF RAJASTHAN

By

Surendra Deo Misra

Professor and Head of Zoology Department, University of Jodhpur

I am very thankful to you for the privilege given to me to preside over the Section B of the Symposium on Natural Resources of Rajasthan which gives me an opportunity to scan the field of biology through the learned papers contributed in this section.

The environmental biologist must recognize and understand the underlying harsh realities and stresses, such as the lack of water, the high temperatures and intensity of solar radiation, the wind velocities and dust storms, to which plants and animals of this hot Saharo-Rajasthan desert are subjected to and to which they have adjusted in various ways. Without understanding the basic laws of the ecosystem, the solutions of arid zone problems will be short-lived.

The desert animals and plants have solved the problems of water scarcity and high temperatures in a number of ways. The reptiles, although seek shelter in the burrows during the day, face the problem of aridity by having developed an impervious integument and solid dry excretion in the form of uric acid. Beetles, which have the ability to increase production of metabolic water from carbohydrates, under arid conditions, use another device. Among the animals, the rodents have solved the problem of aridity and temperatures by escaping from both and remaining inside the burrows made by themselves, during the day where the relative humidity is 30 to 50 per cent compared to 0 to 15 per cent outside. In this way they sweat less, not using water for temperature regulation, but conserving it by excreting very concentrated urine. For temperature regulation, the sheep and the camel have solved their water, budget problem differently from others. The camel can drink incredible quantities of water at a time, as much as 30% of its own weight, but economises its use drastically for thermal regulation. He would allow its body temperature to rise within range of 6°C without

FAUNAL COMPOSITION OF RAJASTHAN[1]

By

P.D. Gupta

Desert Regional Station, Zoological Survey of India, Jodhpur

I—Introduction

The fauna of Rajasthan is poorly known, mainly due to two reasons. First, because formerly it comprised of many princely States, some large and mostly small, which had little interest in the faunistic wealth of the area except either for game or for religious sentiments prevailing among a section of the people. Secondly, the extreme arid climate and the vast desert areas hampered the progress of faunistic surveys. As a result, we hardly find any reference to the fauna of Rajasthan in the literature up till the middle of the last century.

Jerdon (1862) appears to be the first to give some information about birds. Subsequently we find increasing but sporadic references to the fauna of Rajasthan. Though more than a century has elapsed, a review of the literature reveals conspicuous lacunae in our knowledge of some of the invertebrate groups which remain almost untouched even today. Therefore, Dr. M.L. Roonwal, during his directorship of the Zoological Survey of India, organised a systematic survey of the fauna of Rajasthan which was conducted by many experts of that department since 1956. The results of the survey are being published in a series of papers under the title 'Fauna of Rajasthan' in the Records of the Zoological Survey of India (Roonwal, 1969; and others).

A brief account of the fauna of Rajasthan is presented here.

II—Review of the Fauna

1. Protozoa

Bhatia (1936) reported a few Ciliophora and has recorded (1938) Sporozoa known till then from the area. Misra (1960) studied the

1) Published with kind permission of the Director, Zoological Survey of India, Calcutta.

psofusely sweating to bring it down. The excess of heat stored during the day is dissipated at night. The raised body temperature reduces heat flow from the environment to the body. The fur on the body tends to minimise the heat gain and the sweating is so scanty that it wets the skin rather than the fur. Concentrated urine is another saving on the precious water. Is it not amazing that camel can tolerate 27% loss of its body weight - twice the dehydratlon that would bring other mammals into lethal explosive heat rise. The birds, though, like reptiles, also excrete solid urine but they need occasionally to drink for thermal regulation. Man, although very poorly adapted to desert conditions, does make up a lot for this handicap in the desert regions. Some of these interesting desert adaptations have been dealt in papers on animal physiology and have attracted world vide attention.

The animal resources of Rajasthan will have to be seen as a segment of the larger understanding of the actual working of the desert ecosystem, which includes a lot of descriptive work summarized in the UNESCO reports on arid zone research from 1955 onwards. The understanding of the resources will be incomplete without also understanding and undertaking highly analytical work, such as, evaluating the rates of production and consumption, the turnover rates of various populations of plants and animls, the action limiting factors, etc. This is relatively a newer, physio-ecological approach to which we have to direct our attention, besides filling many gaps here and there in our knowledge of the faunistic composition of Rajasthan to which one of the papers will draw your attention.

We have received 26 papers for this section under five headings. The largest number was contributed on animals harmful to man, with special reference to grasshoppers, locusts, termites and nematodes as parasites on plants. Following this, an ample number has been submitted on wild life and animal behaviour.

I hope these papers and discussions on them will form a basis for, not only properly evaluating the animal resources of Rajasthan, but also giving guide lines for reorientating biological research quickening the pace of development of the state.

namatodes. Recently Johnson (1965-68) has contributed towards our knowledge of the namatode parasites of animals. Khera (1965-67) studied free living nematodes; Tikyani and Khera (1968 a, b), Tikyani *et al.* (in press) and Kumar and Khera (in press), have studied the nematode parasites of plants of Rajasthan.

Acanthocephala : Information about this group of worms from Rajasthan is not available in literature.

Rotifera : This group appears to be untouched.

7. *Annelida*

Chaetopoda : A few species of earthworms have been reported by Stephenson (1923).

Hirudinea : Harding and Moore (1927) have described leeches of Rajasthan.

8. *Arthropoda*

Crustacea : Adams (1899) mentioned a few species known from western Rajasthan. Lindberg (1942) studied Crustacea of Jodhpur. Brehn (1950) studied some of the fresh water forms. Mathur and Sidhu (1957) reported the occurence of the genus *Apus* (Notostraca) from Pilani. Sidhu (1959) has also provided a list of Crustacea found near Pilani. Tiwari (1952) described two new species from southeren Rajasthan. Ramakrishna (1951) reported *Paratelphusa (Barytelphusa) jacquemontii* Rathbum. Tiwari (1959, 1962) described a few more aquatic forms and reported (1962) a few fossil shrimps from Kapurdi area. Baid (1958) reported *Artemia salina* from Sambhar Lake and Lin (1964) made a preliminary study of crustacean fauna of Sambhar lake. Biswas (in press) has studied Cladocera of Rajasthan. Glaessner and Rao (1960) described a new species of a fossil crab from Kapurdi in Barmer district.

Arachnida : Pocock (1895) described *Galeodes agoles* from Bikaner. Shariff (1928) studied Ixodiade from U.P., Gujarat and Rajasthan. Tilak (1964) reported a six legged spider, *Crossopriza iyoni* from Pilani. Tikadar (1966) described three new species and reported ten other species found in this area.

Insecta

General : Adams (1899) mentioned a few insects of medical importance from western Rajasthan. Beeson (1941) gave an account of Forest

incidence of opalinids in *Varanus monitor* Linn. from Bikaner as also in lizards from other areas. Mahajan (in press) studied free living Sarcodina, Flagellata and Ciliata. Among fossils, Foriminifera have been studied by many geologists, particularly by Subbotina *et al.* (1960) and Singh (1951-57).

2. *Porifera*

Annandale (1911) has included the information about the Porifera known from Rajasthan. A few unidentified, one identified, fossil forms are reported by Subbotina *et al.* (1960).

3. *Coelenterata*

No living forms are known. A few unidentified fossil forms have been reported by Lubimova *et al.* (1960) and Oldham (1886).

4. *Bryozoa*

Living forms are not known but *Polypora ampla* and other unidentified fossil forms have been reported by (Shah, 1963) and Subbotina *et al.* (1960) respectively.

5. *Platyhelminthes*

Turbellaria : No work appears to have been done on this group in Rajasthan.

Trematoda : Gupta (in press) has contributed towards the trematode parasites of western Rajasthan.

Cestoda : Adams (1899) included a few cestodes in the list of helminths found in western Rajasthan. Southwell (1930) has included some species found in Rajasthan. Recently Rathore *et al.* (1955) has studied cestodes of sheep in Rajasthan, and Mukherji (in press) has studied these parasites from western Rajasthan.

6. *Nemathelminthes*

Nematoda : Adams (1899) has included a species known from Marwar. Rathore *et al.* (1955) have studied parasites from sheep. Baylis (1936, 1939) has mentioned many species from this area. Prakash and Sharma (1955) reported the mortality of hedgehogs due to

Bingham (1905, 1907) dealt with butterflies found in India. Kushwaha (1960) described lepidopteran fauna of *Udaipur*. Macpherson (1927) described butterflies collected at Jodhpur and Mt. Abu. Mathur and Chempakavalli (1961) studied the butterflies of Pilani. Meyrick (1911) described *Myrmecozela metrophora*, a microlepidoptera from Ajmer. Srivastava (1958) reported a new cutworm pest of potato in Rajasthan. Talbot (1939, 1947) included in Fauna of British India series the butterflies from this area. Kushwaha *et al.* (1964) recorded *Chlumetia transversa* Walker (Noctuidae), a pest of mango at Udaipur.

Coleoptera : Achary (1938) studied the distribution of *Sternocera nitidicollis* (Fam. Buprestidae) in Rajasthan (Mt. Abu) and Gujarat. The works of Andrewes (1929, 1935) on the family Carabidae, Arrow (1910-50) on Lamellicornia, Clavicornia groups of beetles, included the material from Rajasthan. Fowler (1912) on Cicindelidae and Pausiidae, Gahan (1906) on Cerambycidae, Jacoby (1908) on Chrysomelidae, include the material from Rajasthan also.

Kushwaha and Sharma (1961) studied beetle predators of Udaipur. Srivastava (1961) reported the Lucerne Weevil *Hypera variabilis* (Hbst.) from south-eastern Rajasthan. Vazirani (1958) reported a few species belonging to Grynidae. Recently Vazirani (in press) has contributed towards the beetle fauna of this state. Gardner (1946) studied larva of *Troxprocerus* Har. (Family Scarabaeidae) from Bharatpur. Kapur and Bhaumik (1966) have recorded four speices of Lady-bird beetles, one of which is a new record from Indian region.

Hymenoptera : The catalogue of wasps and bees described from Indian region since 1897, prepared by Aiyar (1916-1917), included the material from this state. Works of Bingham (1897, 1903), Morley (1913) include the material known till then from Rajasthan. Nurse (1903, 1904, 1909) described a few species belonging to the genera *Tachytis*, *Pseu*, *Gorytes*, etc. from Mt. Abu. Wroughton (1892) contributed a good deal of information about ants from Mt. Abu. Turner (1912a,b) reported many species of *Cerceris*, and described a new species *Cerceris protea* from Deesa in Gujarat and Abu in Rajasthan.

Diptera : Works of Barraud (1934) on Megarhinini and Culicini; of Brunetti (1912, 1920, 1923) on Nematodera, Brychycera and Pipunculidae, Syrphidae, etc.; of Christophers (1933) on Anophelini; and of

Insects. Cotes (1893) described locusts and other Acrididae with notes on their bionoimics. A comprehensive survey of insect fauna of Pilani has been reported by Baid (1959) and Mathur *et al.* (1956). Kundu *et al.* (1961) reported the results of their survey of insect population collected with light trap at Pilani. Pruthi and Bhatia (1952) pointed to the peculiarities of the insect fauna of Rajasthan desert and the share of insects in its maintenance. Roonwal (1954, 1956) reviewed the progress of entomology in India, including Rajasthan, during the period 1938-50. Srivastava (1959) studied insect pests of maize.

Orthoptera : Dirsh (1951) reported a new injurious grasshopper from Ajmer. Kirby (1914) included, in the Fauna of British India, the material from Rajasthan. Roonwal (1961) published a bibliography for faunistic as well as other aspects of the family Acrididae througout the world.

Dermaptera : Burr (1910) included the material from Rajasthan in the Fauna of British India Series.

Isoptera : Kushwaha (1960a, b) reported the results of his termite survey around Udaipur. Roonwal and Bose (1960-69) have given a good account of termite fauna.

Odonata : Fraser (1921-1936) dealt with material from Rajasthan along with that from other parts of India.

Thysanoptera : Ananthakrishnan (1954) included the material from Udaipur. Beeson's work (1941) is also useful. Singh (1950) studied the material from Ajmer. Bhatti (1962) described *Hyalopterothrips roonwali* from Jodhpur.

Hemiptera : Distant (1902-1918) forms a good series on the knowledge of the group in Rajasthan. Joseph (1961) studied *Sardia rostrata* Melichor from Ajmer and Mt. Abu. Kumar (1959) reported a *Urentius* species from Pilani. Behura (1963) summarised the knowledge of Indian aphids including those from Rajasthan. Srivastava and Vaish (1964) reported *Hemaspidoproctus cinereus* Green, a coccid pest of guava, from Ajmer, Jaipur and Bharatpur areas.

Lepidoptera : Hampson (1898) appears to be the first worker on moths of Rajasthan and reported *Euphyra rufaria* from Ajmer as also (1910) *Chasmina judicata* Walk. Bart, (1905, 1906, 1908 and 1912) gave an account of moths from India. Bell (1909-1925) dealt in detail with the butterflies from India. His work includes the material from Rajasthan. Bell and Scott (1937) gave an account of moths from India.

of Pilani. Wall (1908, 1920) has treatised common Indian snakes including those from Rajasthan and while reviewing (1922) the genus *Amplycephalus* reported *A. monticola* (Cantar) from near Jaipur. Wall (1923-25) gave a list of snakes of Indian Empire including Rajasthan.

Aves : Adam (1873-74) studied birds from Sambhar lake and its vicinity. Ali (1953, 1958) reported some of his observations on birds at Bharatpur. Butler (1875-76) gave an account af avifauna of Mt. Abu and northern Gujarat. Hume (1878), while describing the birds of draught, dealt with the birds of Jodhpur area. Jerdon (1862-1864), in his book on birds of India, included those which were known from here. Barnes (1886-91) gave an account of birds nesting in western India including Rajputana. Meinertzhagen (1900) reported the occurrence of the Great Blach-backed Gull *Larus marinus* in Rajputana. Newnham (1900) recorded the occurrence of a few uncommon birds in Rajputana.

Baker (1900) gave an account of ducks and their allies from India including Rajasthan. He reported (1908) some important additions from Mt. Abu, and subsequently (1912) the occurrence of *Eupodites edwardsi* from Rajputana.

Donald (1918), while giving an account of birds of prey of Punjab, included some of those found also in Rajasthan.

Home (1926) reported the occurrence of *Anas brachyrhynchus* and *Anas boscas* in Jaipur. Stables (1923) reported *Anas platyrhyncha* from Rajasthan. Prater (1926) reported the occurrence of Pallas' sandgrouse, *Syrrhaptes paradoxurus* from Bikaner for the first time within Indian limits. Trench (1927) observed the breeding of spotbill duck, *Anas poecilorhyncha* and later (1930) of great sone-plover *(Oedicnemus recurrvirostris)* at Udaipur. Whistler (1928) studied the migration of pied crested Cuckoo, *Clamator jacobinus* over Rajasthan, U.P. and Gujarat. He reported (1938) on an Orinithological Survey of Jodhpur State.

Simmons (1930), while studying the migration, observed the pied Crested Cuckoo, *Coccystes jacobinus*, in Ajmer and again reported (1948) the occurrence of Cuckoo-shrike, *Lalage sykesii*, at Abu and Ajmer. Acharya (1931) reported the occurrence of *Clamater jacobinus* Boddaert from northern Gujarat and Rajasthan. Briggs (1932), while studying the migration of *Tchitrea paradisi*, observed this bird in Rajasthan. Singh (1933) recorded the occurrence of Great Crested Grebe (*Podiceps c. cristatus*) in Bikaner. Eates (1939), during his study on the status and nidification

Abubertin and Smart (1940) on Calliphoridae include the material till then known from Rajasthan.

9. *Mollusca*

Works of Blandford and Godwin-Austen (1908) on Testacellidae and Zonitidae; of Gude (1914, 1921) on Trochomorphidae-Janellidae and land operculates; and of Preston (1915) on freshwater Gastropoda and Pelecypoda give useful information about Mollusca. Recently Ray (in press) reported the result of his studies on molluscs of this area.

10. *Vertebrata*

Pisces : Day's (1889) work, although still a landmark in Indian Ichthyology, provides little information about the fishes of Rajasthan. One can only guess from the distribution of various species of fishes reported by him that some of them may be found in Rajasthan. Hora and Mathur (1952) studied the Palaeogeographical features of Rajasthan as evidenced by the distribution of fishes. Mathur (1952) was the first to make a systematic study of fishes from southern Rajasthan. Krishna and Menon (1958) reported eleven species of fishes from Jodhpur. Datta Gupta *et al.* (1961) studied fishes from lakes of this area. Misra (1962) included in his aid to the identification of commercial fishes those found in this area. Moona (1962) reported 22 species from Bharatpur district. Datta and Majumdar (in press) studied a large collection of fishes made by various survey parties of the Zoological Survey of India.

Amphibia : McCann (1932) studied some of the Batrachians from this area. Recently Kripalani and Murthy (in press) descrided the Amphibia of Rajasthan, and reported eight species from this area.

Reptilia : Blanford (1879) studied a collection of reptiles from Ajmer. Murray (1887) gave an account of reptiles of Western India including this area. Boulenger (1890) included some of the species known from this area. Annandale (1906) reported the occurrence of some of the reptiles of desert tracts from south India. Bannerman (1907) studied the distribution of the varities of cobra in India including Rajasthan. Dave (1961) studied ecological associations of reptiles of Rajasthan. Krishna and Dave (1956, 1961) gave the distribution of reptiles in the desert areas of Rajasthan. Sunder Singh (1960) studied Ophidia

Krishna and Prakash (1955) studied the distribution of hedgehogs in the desert of Rajasthan. In (1956) these authors studied the systematics, ecology and distribution of mammals of desert of Rajasthan, and later (1961) provided further information on the mammals of Rajasthan desert. Gee (1958) studied 'wild' cattle of Bharatpur.

Prakash (1956a) has given valuable information on mammals of Rajasthan desert and provided (1956b) an additional list of mammals from the same area. Prakash (1958) enlisted the vertebrates of Indian desert in which he dealt with mammals only. He studied (1958b) extinct and vanishing mammals of desert of Rajasthan and problems of their preservation. Parakash (1960) reported the occurrence of a few more mammals and discussed zoogeography of this area. Prakash studied the systematics of bats from Rajasthan (1963), and zoogeography and evolution of mammalian fauna of this area (1963b).

Recently Gupta and Agrawal (1966) reported the occurrence of Indian hairy-footed gerbil, *Gerbillus gleadowi* Murray from Kolayat, Sikar and Jodhpur. Agrawal (1967) recorded *Rattus (Millardia) gleadowi* (Murray) and *Pipistrellus dormeri caurinus* (Thomas) from Jodhpur. Prakash and Jain (1967) reported *Rattus meltada* Gray and *Gerbillus dasyurus* from Jodhpur.

III—ACKNOWLEDGEMENT

The author expresses his gratefulness to Dr. M.L. Roonwal, Vice-Chancellor, Jodhpur University, Jodhpur, for allowing to consult the manuscript of his paper. Sincere thanks are due to Dr. S. Khera, Reader in Zoology Department, University of Jodhpur, for supplying the information regarding the work done in his laboratory, and to the Director, Zoological survey of India, for the information regarding the papers submitted for publication in Fauna of Rajasthan series.

IV—Summary

The existing knowledge about various groups of animals has been briefly reviewed and a selected bibliography on the Rajasthan zoology has been given in this paper. As a result of the study it has been observed that certain groups of animals have not yet received attention of systematic zoologists and that an intensive collection and their study could provide useful information about the faunistic wealth of Rajas-

of *Merops p. persicus* Pallas, reported its breeding in Rajasthan. Lowther (1940-44) studied some birds found in U.P. and Rajasthan.

The Private Secretary to His Highness the Maharaja of Bikaner reported (1946) the occurrence of *Anser fabalis* Barllon from Bikaner. Battye (1947) reported the occurrence of *Falco jugger* Gray at Mt. Abu. Pratar *et al.* (1948) reported the occurrence of *Falco jugger* Gray at Mt. Abu. Biswas (1949) studied some of the birds of southern Rajasthan. Shivrajkumar (1949) reported the occurrence of Woodcock, *Scolopax rusticola* Linn. at Mt. Abu. Marien (1950), while studying Asiatic Meropidae, included those found in Rajasthan, U.P. and Gujarat. Recently Roonwal (1959) suggested the possibility of establishing a breeding centre for Ostritch at Bikaner. Ripley (1952) gave an account of vanishing and extinct bird species of India including those in Rajasthan, and included in his synopsis (1961) the majority of the birds found in Rajasthan.

Mammalia : Blanford (1888-91) included many species known from this area. Dang (1959) studied the 'Wild' cattle of Rajasthan and U.P. Ellerman and Morrison-Scott (1951) included most of the mammals known from Rajasthan upto 1946. Blanford (1897), while studying the races of large Indian squirrel (*Sciurus indicus* Erxleben), reported *S.i. bengalensis* from Jaipur. Erskine (1908), in the Imperial Gazetteer of India (Rajputana), gave a good account of mammals found in various districts of Rajasthan. Anonymous (1911) report on the mammalian fauna of India, Burma and Ceylon included also those from Rajasthan area. Ryley (1914) published partial account of 'Mammal Survey of India' dealing with material collected from Palanpur (Gujarat) and Mt. Abu (Rajasthan). Wroughton's studies (1908-21) include the material collected in Rajasthan by 'Mammal Survey of India', and other parties. He described (1912) a new species *Hystrix cuneiceps*, the Rajputana porcupine, from Cutch and Rajputana. Thomas (1915, 1923) studied mongoose and rats collected by 'Mammal Survey of India' which include the material from Rajasthan. Livesey (1922) reported a lion being shot near Kotah. Lindsey (1929) gave the results of his studies on shrews collected by 'Mammal Survey' parties.

Pocock's studies on foxes (1936), mongoose (1937) and otters (1940) include the material from Rajasthan. Sinha (1946) reported the occurrence of an albino boar from Udaipur. Kinnear (1952) gave a history of Indian Mammology which included also that of Rajasthan.

than. The principal groups which need immediate attention are earthworms (Annelida: Oligochaeta), Turbellaria and monogenetic trematodes, ticks and mites (Arachnida), Myriapoda, and a few groups of insects like Mallophaga, Collembola, etc. The parasitic Protozoa and Crustacea, etc., have also remained untouched and their study could also be interesting.

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USEFUL ANIMAL PRODUCTS OF RAJASTHAN

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I—INTRODUCTION

In this paper, I would restrict myself to animal resources available in Rajasthan where the livestock population is one tenth of the total livestock population in India (1956 census). Rajasthan produces wool upto the extent of 45 per cent of the total production of wool in the country. The Nagori breed of cattle is famous all over India and is one of the prize breeds. It has been developed through generations and has adapted itself to extreme variations of temperature. During the hot months the heat is apt to be intense during the day but nights are pleasant. Scorching winds blow with great violence during the months of April, May and June, and during this period sand storms frequently occur. There are persons known as *Banjaras* who have taken to buying and selling cattle as one of their main activity. They move from place to place, selling their animals and grazing their stock on the way.

'Bikaneri sheep' have been quite popular all over the country and this breed has its origin in Rajasthan. Some sheep of this breed yield upto 9 lbs. of wool which is the highest in India. The wool is of good variety and the sheep have learnt to live and flourish in the unfavourable and exacting conditions met within Rajasthan. The other breed, "Marwari", of the Jodhpur Division is also worth mentioning.

The camel is, by necessity, a useful animal for Rajasthan. It is well known that it requires very little water in comparison to other animals. In places where there are no roads, where motor cars etc. cannot go, animal transport becomes the only means of conveyance, and here camel serves the purpose very well in remote areas, and agricultural operations where facilities for cheap electric power are not available.

1 (*a*). The wool industry should be developed and all possible efforts made to increase wool production. For the utilization of the wool produced, it would be necessary to have a woollen mill in the State. Those who are engaged in wool production are poor and illiterate and so governmental patronage is necessary. The question of forming a Board consisting of wool producers and the woollen industry may be considered.

(*b*). With a view to derive maximum profit with minimum cost, it would be necessary to have a well planned slaughter house and meat processing factory for mutton. The location of this factory should be near the rail head and where ample water and cheap electricity is available. Perhaps this proposal may appear to be a little out of place but experience has proved without any doubt that 'selection of sheep for wool production' has no meaning till effective methods have been worked out for the disposal of the culled stock.

2 (*a*). Rajasthan is not suited for the rearing of buffaloes and all milk that is produced is from cows. Cow keeping, milk production, milk processing and dry milk powder factories can be established in the State, and by so doing the farmers who keep animals would get better return for the milk produced. The business of supplying animals to the other parts of the country could be better organized by publicity and high-lighting the good points in favour of the famous Nagori breed of cows.

(*b*). Keeping in view the sentiments of the people, it is suggested that 'carcase utilization centres' should be organised all over the State so as to derive maximum benefit in the form of bonemeal, tallow, meat meal, hides and the manufacture of other ancillary products from dead cows and bullocks which practically go a waste at present. The profits derived may be distributed to the cattle owners who supply the dead animals.

IV—Summary

According to the 1956 census, the population of livestock in Rajasthan is one-tenth of the total livestock in India. This State is producing upto 45 % of the total production of wool in the country. Proposals for the economic development of Rajasthan through this industry have been made. A few suggestions for making the best use of animal resources are given.

II—PLANNING FOR ECONOMIC DEVELOPMENT

For the economic development of Rajasthan, the two alternatives perhaps may be, first, the starting of new industries, and the second, the development of industries which have been existing for hundreds of years. In the later case, the advantage is the availability of trained personnel, while in the former persons have to be trained.

For economic development of Rajasthan *gosamvardhan* and 'sheep farming' are most suited. The application of modern genetics, recent developments in veterinary medicine, developments in wool technology and dairy farming should all be applied and a planned development in all its aspects carried out in a determined way. The region is well suited and the raw material (cattle and sheep) of good quality are already available. Attention to breeding, feeding, management and control of diseases should be the pillars for the development of these industries.

The production of wool and the storage of wool so that it does not deteriorate, and, likewise, breeding of cows and the processing of milk, are essential for the success of the project. The marketing of products has become quite a specialised branch today, and money is the greatest incentive for the development of an industry. The producers of milk and wool should get proper return which should in no way be less than for a person engaged in any engineering enterprise. If the economic condition of *banjaras*, shepherds and persons engaged in rearing sheep, are improved it would, in due course of time, create a condition of the so called 'self generating economy'. The State has to start, take risks, guarantee profits, give protection to those engaged in the work and help those individuals who cannot help themselves.

Camel breeding, due to necessity and the piculiar situation existing, has to be developed for rural transport and for better standard of living. Its importance is also great for defence purposes.

In the end it may be pointed out that if these measures are taken in their proper perspective, it would be possible to develop the above two industries for the benefit and well-being of the Rajasthan and its people.

III—LOOKING AHEAD

With a view to make the best use of animal resources the following suggestions are made :

BIOLOGICAL CLOCKS IN FARM ANIMALS

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I—General Considerations

It has long been known that most animals, both vertebrate and invertebrate, are extremely regular in their behaviour. The switch from Greenwitch Mean Time (G.M.T.) to British Standard Time (B.S.T.) in spring and the change back in autumn are a constant source of irritation to British farmers who complain that it upsets milking schedules because cattle take some days to adjust to the hour's difference. Nor are cattle the only animals to be affected: the sense of time of the farmer's dog and the feeding rhythms of his animals are equally disturbed. Only during the last 30 years or so, however, has it been realised that the daily rhythms of animals are not just responses to diurnal changes of the environment, but are manifestations of an internal or 'endogenous' physiological periodicity which persists, often for a considerable while, under laboratory conditions of constant light or darkness, temperature and humidity. Indeed, although for 20 years previously it had been known that bees possess a time sense, the term 'biological clock' did not come into general use until about 1952 when it was shown that the solar navigation of birds is time-compensated (Kramer, 1952; Matthews, 1954). From this discovery dates study of diurnal rhythms in terms of their relationship to an internal 'clock' system.

Although animals often do the same thing each day at a regular time, as when cows gather round the barn just before milking, such behaviour may vary from season to season. Grazing animals, for example, are likely to be more active at night during hot weather and less so in winter. In addition, seasonal changes in behaviour are produced by changes in the breeding cycle.

The study of biological rhythms or clocks is thus comparatively new, but its importance is rapidly becoming apparent, not only in relation to animal physiology and behaviour, but to their applied aspects,

readings were significantly increased by supplementary feeding, but afternoon readings were unaffected by the plane of nutrition. Rectal temperatures were positively correlated with the dew point in the morning and, later in the day, with direct sun temperatures 4 hrs. earlier (Hutchinson and Mabon, 1954). It should be remembered, however, that several different types of rhythm may co-exist simultaneously in the same animal, and may, or may not, be inter-related,

During autumn and spring, in temperate climates, sheep leave the place where they have spent the night and go out to graze. The flock follows a regular route around the pasture. Every two hours or so, the animals lie down and start chewing the cud, for sheep never graze continuously but rather in cycles interrupted by periods of rumination, rest and idling. The longest periods of grazing occur at dawn and between late afternoon and dusk; the incidence of night grazing depends on the temperature and the prevalence of flies (Hughes and Reid, 1951).

Cattle graze less than sheep and over 4 or 5 periods each 24 hours. The main grazing periods occur just before dawn, in the middle of the morning, in the early afternoon and near sundown : of these, the most continuous are the first and last, while the intermediate periods are rather variable. Night grazing is less sharply defined and occurs more frequently in summer since, in hot weather, the animals prefer to rest and ruminate during the heat of the day. In any given locality, the commencement of early morning grazing is correlated with the season of the year (Hughes and Reid, 1951).

II—PHYSIOLOGICAL MECHANISMS

The circadian rhythm of an animal is a manifestation of its endogenous clock or clocks. The question arises as to how these clocks operate, and three theories have been proposed in explanation. According to the first, all rhythms are basically exogenous and depend ultimately upon cosmic 'clues'. Man-made clocks are of two general types — those with intrinsic timing, such as the hourglass, and extrinsic clocks like the sundial and electric clocks, which depend upon the inflow of timing information. According to this theory, biological clocks depend upon an inflow of exogenous or extrinsic factors. In addition to obvious changes in light intensity, temperature and humidity,

including medicine and veterinary science. It is now generally believed that most daily activity rhythms represent self-sustained oscillations that are free-running under constant conditions and have their own inherent frequency which approximates to 24 hours—hence the term "circadian", derived from the Latin *circa* (about) and *diem* (a day).

Some of the physiological rhythms of animals, such as the spontaneous discharge of nerve cells or the beating of the heart, have a comparatively high frequency. Others, like sexual cycles, may have a periodicity extending over weeks or months. In general, high-frequency cycles depend more upon the morphological and physiological characteristics of an animal, whereas long-term rhythms tend to be correlated with diurnal, lunar or seasonal cycles of the environment. Although in this article only circadian rhythms are considered, the distinction between the different types of cycle is not absolute. Heart rate is clearly dependent upon the size of an animal, its surface-volume ratio, circulatory efficiency and so on—features that bear no particular relation to astronomical time. Nevertheless, it is well known that a 24 hour periodicity is superimposed upon this and the rate of heart beat tends to decrease during sleep.

Under natural conditions, circadian rhythms are synchronised with, or entrained to the period of the earth's rotation by means of periodic factors of the environment. As the rhythm is not a direct response to these, however, such factors have been referred to as "clues", "synchronizers" or "*zeitgebern*" (time-givers). Their function lies in keeping the physiological rhythm of the animal in phase with the cycle of the environment. The term "exogenous" is applied to rhythms that represent a direct response to cyclical environmental changes. Unequivocal examples of exogenous rhythms are comparatively rare, however, and they probably often represent "endogenous" rhythms which, in the absence of clues, rapidly get out of phase with the cycle of the environment (Cloudsley-Thompson, 1961).

An example of an exogenous rhythm is afforded by the temperature rhythm imposed on cattle in hot climates. It was found in Tanzania that the diurnal variation of rectal temperature from 7.30 to 15.30 hrs. had a range of 2 deg. C (3.5 deg. F) while the air temperatures ranges about 6.5 deg. C (12 deg. F). The variation within morning readings was greater than within afternoon readings. Low morning

very similar, but those animals from different litters varied. These results have been interpreted as proving the genetic origin of the natural period on the ground that, if the rhythm were learned, there would have been an accumulative error which would have caused the third generation to have a frequency of other than 23.5 hour (Cloudsley-Thompson, 1961; Harker, 1958).

If circadian rhythms are indeed inherited, the problem arises, why do they tend to die away in some animals after long periods under constant conditions ? Circadian rhythms occur in unicellular organisms as in multicellular ones, and it has been suggested that the rhythm of a multicellular animal may disappear when its cellular clocks are no longer synchronized with one another. Since a single exposure to light or an abrupt change in temperature can be sufficient to engender the reappearance of a rhythm, this hypothesis seems not unlikely to be correct. For this reason, therefore, exogenous rhythms, which do not persist under constant conditions, may merely represent endogenous ones that rapidly get out of phase with the environment. Moreover, many attempts have been made to locate a rhythm control centre in mammals, using operative procedures. These have included removal of the stomach, adrenals, pituitary and thyroid glands, as well as lesion of the frontal brain tissue and corpus striatum of the rat, and removal of the cortex of the dog. In no case, however, was the rhythm eliminated completely.

Circadian rhythms of activity have been studied extensively in mammals, especially rodents, and are usually remarkable for their persistence. For example, the daily rhythm of nocturnal doormice persists upto 18 months in darkness, although in constant light, the daily active period becomes progressively later. Similar results have been obtained with white rats, mice and hammsters. The persistence of endogenous rhythms under controlled environmental conditions has not yet been investigated experimentally in domestic animals, but there is no reason to suppose that these should differ from other mammals.

If functions other than locomotory activity are studied, it is found that these too show endogenous rhythms. They include rhythms of heart rate, metabolism, blood sugar, blood eosinophils, mitosis, body temperature, excretion rate and so on (Halberg *et al.*, 1959). Many of these rhythms are inter-related, but some of them can be separated

which can be eliminated experimentally, there are diurnal changes in other forces such as gravity, barometric pressure, high-energy radiation, and magnetic and electric fields. Such information, if indeed it does provide the timing information of biological rhythms, must be transmitted in an extremely subtle manner and depend upon some universal-time geophysical rhythm with simultaneous world-wide changes, such as alterations in magnetic or electrostatic sensitivities. It has so far proved impossible to devise an experiment that will differentiate between a genuinely innate clock mechanism and one derived from extrinsic sources, since it is possible, by analogy, to alter the hands of a clock relative to the position of its mechanism. The theory is unassailable in terms of logic and the critical experiment to prove or disprove it can probably be conducted only in outer space (Brown, 1962).

The second theory assumes that when animals develop from the fertilized egg or zygote, they are initially arhythmic. But they soon learn a 24 hours rhythm from environmental conditioning or from the behaviour of their parents through 'imprinting'; a type of learning that takes place very quickly and is almost irreversible (Thorpe, 1963). Although not entirely disproved, there is little evidence in favour of this theory and much against it. For example, young rats have been raised in total darkness and constant temperatures and yet showed a circadian rhythm of activity and rest, monitored by their use of running-wheels. That this had not been learned through the influence of their mother, whose own rhythm would have been reflected in the times at which she fed her young, was proved by exchanging a 'foster' mother with the real mother randomly at different times during the day and night.

The majority of biologists working in the field of biological rhythm now assume the presence of an inherited circadian clock and there is considerable evidence in favour of this hypothesis, emanating from the study both of vertebrates and invertebrates. For example, chicks hatched and raised in constant dim light and without any known periodic environmental factor developed a rhythm having a frequency of slightly less than 24 hours.

In another experiment, different strains of mice were maintained under constant environmental conditions, some in light and others in darkness. Within each litter, the periodicities of individul mice were

all long sequences of six or more eggs terminate in the evening at 19.00 hr.

When the daily light cycle is replaced by constant lighting, hens continune to produce eggs at regular, but slightly longer, intervals than before, and regular oviposition cycles are maintained by a small proportion of individuals even in constant darkness.

Although most egg sequences are initiated in the early part of the natural day, regardless of light or activity, hens receiving artificially short days (8 hr. light and 8 hr. dark) reached 50 per cent production three weeks later than a control group which received 16 hr. light daily (Woodard *et al.*, 1962). Similarly, short cycles of 16 and 18 hr. length respectively retarded sexual maturation in both male and female Japanese quail, *Coturnix japonica*, and tended to upset the continuous laying patterns in some hens, possibly through interference between the exogenous short-day cycle and the natural circadian rhythm.

The endogenous nature of egg-lay in birds has been demonstrated by experiments in which ovulation in regularly laying chickens was suppressed by intramuscular injections of 1.0 to 2.5 mg. oestradial benzoate. The following day, however, ovulation took place at the usual time. In other words, egg-laying could not take place until the normal time next day, irrespective of the time at which the inhibitory factor was removed. From this, it was concluded that the neural mechanism thought to control the release of the ovulation-inducing hormones from the anterior pituitary followed a 24-hr. rhythm in its response to other excitatory hormones (Fraps, 1954).

Under natural conditions, circadian rhythms of activity are synchronized with, or entrained to the period of the earth's rotation by means of periodic factors of the environment. Of these factors or clues, light is undoubtedly the most important. This is related to the fact that, of all physical factors of the environment which change over the 24-hr. period (such as temperature, humidity, barometric pressure and so on), light intensity is the most consistent and reliable (Cloudsley-Thompson, 1960, 1961).

In rodents, the period of spontaneous locomotory activity is lengthened in constant light. Thus the time of the daily period of activity becomes progressively later on successive days and may be shifted steadily round the clock, with no tendency to be fixed at any particular time of the solar day or night. The trend in the rate of

experimentally, which implies that there is no single clock system. For example, if rats are illuminated from 06.00-18.00 hrs., their main feeding time is changed from midnight to noon, but the pattern of running activity does not change although the light inhibits locomotion induced by hunger. Experiments have been carried out on men working abnormal time routines in the Arctic during the summer, when perpetual daylight is experienced and other environmental conditions show little variation. Specially adjusted 21-hr. and 27-hr. wrist-watches were worn so that, in the intervals between recording cycles, when the subjects were free to pursue their own interests, they would always live according to the experimental time routines. It was found that the rhythm of body temperature became adapted almost immediately to the abnormal time routines, in marked contrast to the excretory rhythms of water, chloride and potassium which showed varying degrees of dissociation. It was suggested that the rhythms of sleep, body temperature and the retention of water and chlorides might be controlled by the hypothalamus, whilst the potassium excretory rhythm might be under the influence of the adrenal cortex (Lewis and Lobban, 1957).

Physiological rhythms under laboratory conditions have not been studied in farm animals, but the existence of circadian excretory rhythms in cattle has long been known. In one experiment, the total dry weight of urine was minimal at 10.00 hr. and maximal at 23.00 hr. The concentration of potassium and the potassium/sodium ratio paralleled this, while sodium concentrations were minimal at 23.00 hr. with maxima at 14.00 and 02.00 hr. The level of phosphorus was low between 14.00 and 16.00 hr. and high between 06.00 and 14.00 hr., whilst dry faecal material had a maximum weight at 14.00 to 16.00 hr. with a minimum at 10.00 hr., and so on.

Numerous investigations have established that the cyclic pattern of oviposition in poultry and other birds is synchronized by daily fluctuations in light intensity. Individual hens with exceptionally high rates of laying nearly always oviposit at about the same time each day. Egg sequences are generally initiated in the early morning and terminated in the late afternoon. Chickens with a low rate of lay usually interrupt egg production for one or more days whenever oviposition time has advanced to fall within the night hours. In turkeys, over 74 per cent of eggs are laid between 12.00 and 20.00 hr. and only 20 per cent between 06.00 and 12.00 hr. Only 5.5 per cent are laid in darkness and

by simple response to cyclical environmental changes. Furthermore, environmental clues are not always regular in the field, for example, the sunrise may be hidden by cloud, and it will obviously benefit an animal to be pre-adapted for some forthcoming event such as dawn or winter. Consequently there must, through the ages, have been a steady selection in favour of an accurate endogenous rhythmicity.

The effect of drugs is greatly influenced by the time at which they are administered, and animals show rhythms of sensitivity to toxic environmental stimuli. Indeed, the functions of the various organs in animals are rhythmically adjusted so that homeostasis is achieved and they are sheltered from regular oscillations of the external environment. The concept of homeostasis, of course, pre-supposes limited variability since some departure from the normal must occur to evoke the appropriate regulatory mechanism. Physiological rhythms, however, are more than mere variations about a physiological norm, for the norm itself is changing rhythmically. It is now well known that the behavioural responses of an animal to a stimulus vary according to the physiological state of that animal and this, in turn, varies according to the time of day or season of the year. For example, at night many nocturnal animals are much more sensitive to environmental stimuli than they are during the day, and the converse also occurs.

Moonlight is more favourable to romance than the harsh morning sunshine, nor is the difference purely psychological. To quote an Arabic proverb, words spoken at night are coated with butter which melts when the sun rises. How many love letters have had their effect impaired by the unfortunately early hour of postal delivery? At present, biological rhythms are largely ignored in animal husbandry (apart from artificial alteration of photoperiod to influence egg-lay). But the time may soon come when basic knowledge of the subject increases to a point at which it can usefully be applied to increase productivity to a far greater extent than at present envisaged.

IV—Summary

Some of the results of switch from Greenwitch Mean Time to British Standard Time in spring and the change back in autumn have been correlated with the internal or 'endogenous' physiological periodicity called 'biological clock'. In this paper only circadian (*circa*, about;

numerous metabolic periodicities at each level of organisation, synchronized into an organic whole. Or, if the control process were one involving a change in entropy rather than heat change, there would be but a slight temperature coefficient and the clock mechanism would tend to be independent of temperature. At present there is little experimental evidence to support any particular hypothesis.

III—BIOLOGICAL SIGNIFICANCE

Two kinds of factors are of importance in maintaining rhythms in animals : (a) Proximal — these are the clues or *Zeitgebern* by which the rhythm is synchronized to the environmental cycle and which include changes in light intensity, day length, temperature fluctuations, seasonal rainfall, lunar phases and so on. (b) Ultimate—these are the factors by which the animal benefits from its response. They include availability of food and breeding sites, comparative absence of predators and parasites, synchronization of breeding adults, seasonal availability of water, absence of inclement weather, seasonal fires or drought.

A proximal factor can sometimes act also as an ultimate factor as in the case of seasonal rainfall which synchronizes the breeding of many tropical birds. A time-sense is involved in the solar navigation of birds, insects and other animals, in the appreciation of changing photoperiod and the consequent synchronization of breeding cycles and other seasonal phenomena.

The timing of an animal's activities is clearly important for a number of reasons. There is an obvious biological advantage to a species in the co-ordination of the activities of its members. Not only do the sexes have a better chance of mating, but the presence of large numbers at a given moment may be sufficient to satiate the appetites of predatory enemies at this vulnerable time. No doubt, too, the times of feeding of many carnivorous animals are related to the activity rhythms of their prey which, in turn, can avoid predators by adjusting their times of activity. As well as gaining protection from enemies, many animals escape competition for food by assuming a nocturnal activity period (Cloudsley-Thompson, 1960).

No doubt many of these generalizations apply, or have applied, either to farm animals or to their wild progenitors. All of them could be carried out more efficiently by reference to an endogenous clock than

BIOLOGY OF THE RODENTS OF RAJASTHAN DESERT

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(With 1 Text-figure and 1 Table)

I—Introduction

Rodents are serious pests of the natural resources in the Rajasthan desert because of the considerable number of species which are distributed almost in every xeric habitat. Besides, the population of certain species of rodent increases to such high levels that they do not leave any vegetation, particularly the edible grasses, for utilization by livestock the maintenance of which is one of the major source of livelihood of people in this desert. In addition to the economic losses by their devastating activities, the rodents disturb the delicate soil-plant-animal balance (Prakash, 1959). Some work on the biological aspects of the rodents inhabiting the desert region has been carried out in the recent past but a severe lacuna remains to be filled in the knowledge of the rodents of eastern Rajasthan and with respect to those inhabiting the irrigated region such as Sri Ganganagar. In this review is discussed the ecological work done so far on the rodents of the Rajasthan desert.

Three families of Rodentia are represented in the desert region (Adams, 1899; Agarwal, 1967; Gupta and Agarwal, 1966; Prakash, 1959d, 1963, 1963a, Prakash and Jain, 1967; Prakash and Purohit, 1967). These are :

Family I. Sciuridae (Squirrels and marmots)

1. *Funambulus pennanti* Wroughton (Northern Five-striped squirrel)

Family II. *Hystricidae* (Porcupines)

2. *Hystrix indica* Kerr (Crested porcupine)

Family III. Muridae (Rats, mice, gerbils)

3. *Gerbillus dasyurus indus* Thomas (Wagner's gerbil)
4. *Gerbillus gleadowi* Murray (Hairy-footed gerbil)

and *diem*, a day), rhythms have been discussed. The question as to how the 'biological clock or clocks' operate and the three theories that have been proposed in explanation of the mechanism of circadian rhythm have been discussed. The biological significance of these rhythms has also been considered.

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son is over, the merion gerbils migrate back to their nearby burrow systems. *Tatera* is found in pairs in each burrow system (Prakash, 1962) in the native grasslands over sandy plains but as many as 14 were collected from a single burrow opening in a ruderal habitat. At Bikaner, the rodents burrow on the sides of walls of houses in the streets of the city and are found in large numbers. They have more or less fully replaced *Rattus rattus* from the city. They enter houses at night for feeding on refuse. *Gerbillus dasyurus* is psammophile although Zahavi and Wahrman (1957) found it to be rock-dweller in Israel, where it digs burrows among stones. *Gerbillus gleadowi* is found on sand dunes; its burrows being located under bushes and also on gravel plains (Prakash and Purohit, 1967). *G. gleadowi* was also collected from *Meriones hurrianae* burrows where it is commensal, thus probably, avoiding any competition with this dominant species of the desert.

Hystrix indica inhabits long tunnels in rocky regions (Prakash, 1964) and *Funambulus pennanti*, the arboreal rodent of the desert, is found near villages in the rocky habitat, otherwise it is commensal with man. It appears to be very adaptive and it has recently been reported from Iran (Ellerman, 1961) and the Andamans (Chaturvedi, 1965). Moore (1960) reported that its range extended towards east (Nepal Terrai) in India. Moore and Tate (1965), while discussing the systematics of the genus *Funambulus*, described the habitats of the species of this genus.

In addition to the edaphic factors, the habitat preference of rodents also depends on the vegetation types. *Gerbillus gleadowi* prefers to burrow under bushes of *Calotropis procera*, *Zizyphus nummularia*, *Capparis decidua* and *Aerva tomentosa* (Prakash and Purohit, 1967), whereas the desert gerbil, *M. hurrianae*, avoids regions having thick grass cover, particularly of *Cenchrus biflorus* and *Erianthus munja* (Prakash, 1964a). It prefers the micro habitat having frequency of grasses like *Aristida adscensionis*, *Lasiurus sindicus*, *Perotis hordeiformis* and *Digitaria margirata* (Prakash *et al.*, 1971). McCan (1927) mentioned that their common haunt is the flats where *Salvadora persica*, a small tree, grows. What is the influence of the occurrence of predators on the habitat preference of rodents can only be ascertained when detailed studies on the former are taken up.

5. *Tatera indica indica* Hardwicke (Indian gerbil)
6. *Meriones hurrianae* Jerdon (Desert gerbil)
7. *Rattus rattus rufescens* Gray (House rat)
8. *Rattus meltada pallidior* Ryley (Soft-furred field rat)
9. *Rattus gleadowi* Murray (Sand-coloured rat)
10. *Mus musculus bactrianus* Blyth (Persian house mouse)
11. *Mus booduga* Gray (Little Indian field mouse)
12. *Golunda ellioti* Gray (Indian bush rat)

II—HABITAT PREFERENCE

Prakash (1964) recognised three main habitats of desert mammals, viz. sandy, rocky and the ruderal, which are chiefly based on the edaphic characteristics, following Blatter and Hallberg (1921). The habitat preference of various rodents is shown in Table 1.

Table 1.—Habitat preference of rodents of the Rajasthan desert

HABITATS			
SANDY		ROCKY	RUDERAL
Sand dunes	Sandy plains		
Gerbillus dasyurus *Gerbillus gleadowi* *Meriones hurrianae* (temporarily)	*Gerbillus dasyurus* *Tatera i. indica* *Meriones hurrianae* *Rattus meltada* *Rattus gleadowi* *Mus booduga* *Golunda ellioti*	*Funambulus pennanti* (occassional) *Hystrix indica* *Tatera i. indica* (near human habitation)	*Funambulus pennanti* *Tatera i. indica* *Meriones hurrianae* (in harvesting season) *Rattus rattus* *Mus musculus*

Most of the rodents prefer sandy habitat, but *Tatera i. indica* and *Meriones hurrianae* occur in almost all other habitats (Prakash, 1962) and the former is found even in highly saline soils. It has been observed that *Meriones* colonise sand dunes when their upper crust is stabilised during the rainy season, but no sooner it dries the gerbils shift back to the more stabilised sandy plains. They also shift or extend their burrows under *Prosopis juliflora* bushes when the pods ripen and fall down. The desert gerbils feed on its seeds. When the fruiting sea-

seasmum or coconut oil may increase the attractiveness of the bait. Since Prakash (1962) found that they feed mainly on the seeds in nature, intake of grasses, shrub and tree species which grow in the gerbil habitat, was found out with rodents maintained in the laboratory (Prakash *et al.*, 1967). *Meriones hurrianae* preferred the seeds of grasses, whereas *Gerbillus gleadowi* preferred the seeds of grasses as well as of tree species. The consumption of seeds of these plants by *T. indica* did not vary much. However, the air dried fruits of *Zizyphus nummularia* (ber) topped the palatability index of all the seeds and provided an important clue to evolve the one-shot baiting technique (Prakash and Jain, 1970) for the control of these gerbils.

Water requirement : The average daily water consumption rates in *M. hurrianae* and *Gerbillus gleadowi* were found to be 0.57 and 3.28 percent of body weight respectively (Ghosh and Gaur, 1966). Considering the comparatively lower water requirement of the former species the authors considered it to be at a more advantageous position than *G. gleadowi* which being nocturnal and thus being less exposed to the dessicating daytime desert environment, are less efficient in economising on the water expenditure in comparison to *M. hurrianae*.

IV—REPRODUCTION

Estrous cycle : The desert gerbil *Meriones hurrianae* breeds freely in the natural environment but it rarely litters in captivity. However, the Indian gerbil, *Tatera indica indica*, has bred in cages although not regularly. The estrous cycles of these two species of gerbils were, therefore, studied by Ghosh and Taneja (1968) who found that average duration of estrous is 4.82 and 6.22 days for *T. i. indica* and *M. hurrianae* respectively. The two species differ significantly in the duration of the interval between vaginal cornification. The actual period of cornification lasts for a maximum of one day for both the species. These authors observed that period of estrous of *T. i. indica* is in conformity with the average durations of 4.0 to 4.8 days reported by Asdell (1946) for various species of *Rattus* and consider *M. hurrianae* as a unique rodent species with respect to the estrous cycle.

Mating behaviour : One case of mating was observed by Agarwal (1965) and detailed observations have been included in Fitzwater and Prakash (1969) in which the behaviour, 'perineal drag' has been

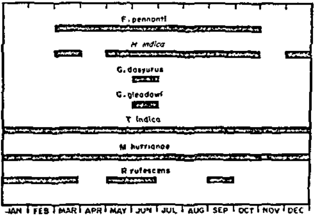
III—FOOD

In nature : Some detailed studies have been made on the food of *Tatera i. indica* and *Meriones hurrianae* (Prakash, 1959a, 1962, 1966 and 1969). Earlier to these studies, Blanford (1888-91) mentioned that *Tatera* feeds on roots and grass, especially *Cynodon dactylon*, seeds and grains, and sometimes cause great damages to *Jowar* and *Bajra* crops; and that *Meriones* feeds on various seeds, especially the nuts of *Salvadora persica*, and on roots. Prater (1965) augmented the dietary of *Tatera* to insects, their grubs, eggs and nestlings of ground birds and smaller rodents. Comber (1910) witnessed a desert gerbil feeding on human faeces.

The stomach contents of *T. i. indica* and *M. hurrianae* were examined every month for a year by the volume method (Prakash, 1962) and it was found that about half the diet of gerbils, all the year round, consisted of vegetative parts of plants, supplemented by seeds (post monsoon and winter) and insects (spring and summer for *Tatera* and summer for *Meriones*). These observations tally with the findings of Prasad (1954a). The fluctuations in the occurrence of various food items were more conspicuous in the latter gerbil, which were in conformity with the changing vegetational eco-system reflecting the availability of different food items. In a later study (Prakash, 1969), when the food preferences of merion gerbil were studied in the field during monsoon by comparing the frequency of occurrence of each species of vegetation in the biotope with that of the unconsumed plant species lying near burrow openings of gerbils, it was revealed that they show a definite preference for palatable grasses, the preference being in the following order : *Cenchrus ciliaris*, *Aristida adscensionis*, *Eragrostis ciliaris*, *Digitaria adscendens*, *Brachiaria ramosa* and *Tragus biflora*.

In captivity : A wide variety of plants and animals (invertebrates and vertebrates) were offered to Indian and desert gerbils in large cages (Prakash, 1959b) and it was found that both the rodents are primarily herbivorous but the former accepts comparatively a large number of species of insects whereas merion gerbils accept members of Orthoptera only. Investigations to find the most suitable bait for poisoning these noxious rodents (Prakash and Kumbkarni, 1962; Prakash *et al.*, 1969) revealed that wheat flour bajra grain as well as flour were most preferred. The addition of 5 to 10 per cent groundnut,

shawi and 1-8 (av. 3.7) in *Meriones longifrons*. Blanford (1888-91) and Prater (1965) mentioned the litter sizes of *Rattus rattus*, *R. meltada*, and *Mus musculus*, to be varying from 7-9, 6-8, and 4-8 respectively. However, in Rajasthan desert we have observed upto 7 and 5 young at birth in *R. rattus* and *M. musculus bactrianus* respectively. One *Gerbillus dasyurus* collected from the field delivered two young in the laboratory in June. Litter size of *Gerbillus gleadowi* was observed to be 2-4 (av. 2.2, Prakash and Purohit, 1967).



Text-fig. 1—Duration of littering activity of rodents in Rajasthan desert.

Breeding season : The data available on the duration of breeding season is presented in Fig. 1 which indicates that the maximum number of rodent species litter in June, the hottest month in the year when the feed available is scarce and all the environmental conditions are adverse for bringing up the young ones. The various possible factors influencing the breeding of the Indian desert hare, *Lepus nigricollis dayanus* Blanford have been discussed by Prakash and Taneja (1969) and in the light of this discussion, it may appear that the day length may be one of the important factors in influencing their littering duration in the year. The littering of majority of rodent species in summer can also be explained since the rodents can adapt to the fluctuations of temperature by being nocturnal and fossorial, their burrows being cooler than the outside environment (Prakash *et al.*, 1965; Fitzwater and Prakash, 1969). The breeding season of rodents, therefore, differs from that of large

described. The same behaviour has also been reported in north American rodents (Eisenberg, 1963) depicting an interesting example of parallel evolution of the same behaviour in these rodents widely separated geographically.

Gestation period : Banerji (1955, 1957) found the gestation period of *F. pennanti* as 42 days. However, there is very little information on the gestation period of the Indian crested porcupine. A female littered in the Bikaner Zoo on 3-6-63 and again on 20-9-63, the difference between the two deliveries was of 109 days. Zuckerman (1953) mentioned for the north African species that the gestation lasts 63 or 112 days (Asdell, 1946; Kenneth, 1947). The Bikaner record is apparently the only one by which a rough estimation of the gestation period of the Indian porcupine can be made. The gestation period of *Tatera i. indica* was observed to be 27-30 days (av. 28.22 days, Prakash *et al.*, 1967) and that of *M. hurrianae* was 28-30 days (av. 29 days, Prakash, 1964b). Long and Evans (1922) and Parkes (1926) mentioned that the period of gestation of *Rattus rattus* and *Mus musculus* was 21.5-22 days and 19-20 days respectively.

Litter size : Banerji (1955, 1957) and Purohit *et al.* (1966) mentioned the litter size of northern palm squirrel to be 2 to 4 but Agarwal (1966) claimed to have observed litter of five in one case. Prasad *et al.* (1966) discussed the biology of reproduction of *F. pennanti*. Blanford (1888-91) and Prater (1965) mentioned that 2-4 young at a time may be born of *Hystrix indica*, but in the London Zoological Gardens Zuckerman (1953) observed that 1 or 2 young were born at a birth. In the Bikaner, Jodhpur and Jaipur zoos, out of 18 deliveries, one young was born in five cases, in 12 cases two were born and only in one case three young were born. *Tatera i. indica* was observed to deliver 1 to 9 young at a birth (average 4.0, Prakash *et al.*, 1971). Khajuria (1965) also observed a brood of six young in Madhya Pradesh and Parrack (1966) reported the birth of a litter of four young in west Bengal in March. Blanford (1888-91), however, mentioned, 'the female has 8 to 12 young at a birth, occasionally, it is said, even more'. Prasad (1954b and 1961) reported that the number of embryos per birth of *T. i. cuvieri* varied from 3 to 10. The size of litter of *Meriones hurrianae* is similar to that of *T. i. indica*, 1-9 (average 4.39, Prakash, 1964b). However, Zuckerman (1953) has mentioned litter sizes of other species of *Meriones* inhabiting deserts of middle-east to be 1-16 (av. 6.5), in *Meriones*

The fluctuations in number of desert gerbil also show an annual trend, the numbers being lowest in summer and highest in winter and spring. The population increase may be mainly due to increase in the rate of reproduction after the monsoon, as directly influenced by the availability of green food at that time. Their numbers are related to soil characteristics, the population being less in clayey and compact soils. An inverse relationship between grass cover and population density was also observed (Prakash *et al.*, 1971).

VI—HOME RANGE

The average home range of male and female *Funambulus pennanti* was found by the minimum home range method (Mohr, 1947) to be 0.21±0.73 hectares and 0.15±0.034 hectares respectively (Prakash *et al.*, 1968). The observed greatest distance between capture points of individual adult male *F. pennanti* was 65.61±4.80 m, for adult female 46.87±5.40 m, for subadult male 41.71±10.93 m, and for subadult female 43.95±1.85 m. The observed range length of adult males is significantly (5% level) more than those of all other groups probably because of higher competition among adult males for mate which are lesser in number than the former.

It was observed that during mating season the males *M. hurrianae* doubled the size of their normal home range, from 88.7±14.3 sq m to 159.9±44.3 sq m. Female home range average 154.7±24.6 sq m. The observed range length of male desert gerbils was calculated to be 16.03±0.98 m or 20.3±2.9 m when the extended breeding range is considered and that of females 18.46±1.5 m (Fitzwater and Prakash, 1969). Work on the home range of *T. i. indica* is in progress and the preliminary results indicate that the range length of male and female *Tatera* is 90 m and 106 m respectively. The home range studies are valuable for establishing the distance at which baiting stations should be fixed in control operations.

VII—BEHAVIOURAL ADAPTATIONS TO XERIC ENVIRONMENT

Diurnal activity : The desert gerbils adjust the timings of their activity outside the burrows to avoid extreme heat and cold of the desert. During the winter they venture out of their burrows late in the morning and remain outside throughout the day, whereas during

wild mammals, most species of which litter during and after rainy season (Prakash, 1960).

V—POPULATION CHARACTERISTICS

Detailed studies on populations have been made only on two species of rodents of Rajasthan desert. Prakash and Kametkar (1967) found a preponderence of males in northern palm squirrel, *Funambulus pennanti*, in the years 1963 and 1964 (2.22 male : 1 female). Agarwal (1965, 1967) also observed 57 per cent males in 88 squirrels. The male to female ratio of new born was 1.1:1, and among subadults 1.83:1 (Purohit *et al.*, 1966). A comparison of these ratios with the adult ratios indicate that female squirrels have a higher mortality rate as compared to male squirrels. During the capture recapture study it was revealed that during 1963 the adult-subadult ratio of *F. pennanti* was 8.7:1 but it decreased to 1.2:1 among males and 2:1 among females during 1964, which may indicate that the older animals either perished in the study area at Jodhpur or migrated out due to heat stress (Prakash and Kametkar, 1969). These authors also found a gradual decrease in the number of squirrels, which was estimated by the Lincoln Index, from April to December 1963, with a minor increase in August. Their numbers remained very low during winter. The number of squirrels trapped varied between months and between years and the per cent squirrels recaptured also significantly varied between years (79.1% in 1963 and 44.4% in 1964). The persistence of marked squirrels stepped down rapidly till eighth month from the month of first capture but after this it decreased gradually. The body weight of freshly captured squirrels is discussed in detail.

Prakash (1964a) has discussed the sex ratios of *M. hurrianae* and found that they fluctuate considerably. During 1954-56 the proportion of male and female was almost equal (49.2 % females) in the population but during 1963-64 it was 63.7 % females. However, Agarwal (1965, 1967) found in his collection of 89 examples (August-January) from Rajasthan 66 % male desert gerbils.

The relative numbers of desert gerbils in three bio-climatic zones of Rajasthan desert were studied in all the seasons by burrow closing opening method (Prakash *et al.*, 1971). The average annual number varied from 31 to 458 per 90×90m experimental plots.

(1967) mentioned that the house crow can also tackle the merion gerbils. Although, in the desert the number of rodent predators is significantly high inasmuch as that Prakash (1964) had recognised 'rodents and hare' as a food centre in the desert, yet we find considerable built up of rodent populations which may suggest that the predator-prey balance is in favour of rodents. This may be probably due to the efficient predator detection by the rodents. Fitzwater and Prakash (1969) observed that due to their hypertrophized tympanic bullae (Prakash, 1959c), desert gerbils are able to distinguish between the noises of wingbeats of harmless and predatory birds, thus escaping from the latter. This may further be confirmed that rodents are really hard to catch when we find stomachs of carnivores full of berries of *Zizyphus nummularia* (Prakash, 1959a).

IX—RODENTS AND DISEASES

No work has been done in Rajasthan on the epidemeological aspect of rodents but the role of *Tatera indica* in maintaining and spreading the plague is worthy of mention. Baltazard and Bahmanyar (1960) obtained results in Uttar Pradesh to show that the spread of infection of plague in rural areas is caused by field rodents, among which epizootic outbreaks flare up, spreading from burrow to burrow and infecting the village rats, *Rattus rattus*. The persistence of rural plague is due to the relatively high resistance to the disease of the Indian gerbil, *Tatera indica*. These authors maintain that the principal role played by *Rattus* is to act on 'liasion rodent' between field rodents and man. In Rajasthan also *Tatera* is found near human habitations and mix with the domestic rats, thus enhancing the chances of spread of plague. This aspect of the study should be taken up for future work by the biologists of Rajasthan.

X—ZOOGEOGRAPHY

The zoogeography and the evolution of the mammalian fauna has been discussed in detail by Prakash (1963a). The various species of rodents inhabiting the Rajasthan desert are 41.7 per cent oriental (*F. pennanti*, *R. rattus*, *R. meltada*, *M. booduga* and *G. ellioti*), 41.7 per cent palaeotropical (*H. indica*, *G. dasyurus*, *T. indica*, *M. hurrianae* and *M. musculus*) and 16.6% endemic (*G. gleadowi*, *R. gleadowi*) in affinities.

summer they restrict their outside activity to early mornings and late evenings (Prakash, 1962) thus avoiding the heat of the day.

Fossorial habit : Most of the field rodents are fossorial in habit, except the squirrel and bush rat. Studies on the burrows of *M. hurrianae* (Wagle, 1927; Petter, 1961; Ganguli and Kaul, 1962; Agarwal, 1965, Fitzwater and Prakash, 1969) have revealed that they are of extensive nature. The extensive burrows provide the desert gerbils a temperature which shows maximum variation of only 1.5°C in any season (Prakash *et al.*, 1965). The burrows remain 13.4°C to 17.7° C cooler than outside environment during various seasons. The burrows also assist the incumbent in the maintenance of the homoestasis. It has been observed that *M. hurrianae*, the diurnal gerbil, does not remain out of the burrow for a long stretch of time and frequently visits the burrows. When it develops some hyperthermia by continuous exposure in outer hotter environment, the desert gerbil intermittently unloads the excess body heat to the cooler surroundings of the burrow (Fitzwater and Prakash, 1969). On the other hand the burrows of nocturnal gerbils, *Tatera indica* (Prakash, 1962) and *Gerbillus gleadowi* (Prakash and Purohit, 1967), are of a simple pattern as they need not maintain a low temperature as these gerbils do not have to unload the heat, like *M. hurrianae*, since they are nocturnal.

Nocturnal habit : Except *M. hurrianae* and *F. pennanti* all other rodents of Rajasthan desert are nocturnal. The percentage of nocturnal animals in deserts is usally higher (Bodenheimer, 1957). Nocturnal habit saves these rodents from the problem of exposure to hot temperatures of the day. This habit is also advantageous since it reduces the pressure of competition from diurnal rodents and predators.

Feeding behaviour : The gerbils have been observed to change their dietary in various seasons (Prakash, 1962). During summer they feed on rhizomes of grasses and insects which have a higher water content as compared to air dried stems or seeds. This change in feeding behaviour is an adaptation to meet their water requirement during summer, although the desert gerbil is capable of sustaining for considerable time without water (Ghosh *et al.*, 1962, 1964).

VIII—PREDATORS

Snakes, raptorial birds and carnivorous mammals are the chief predators of the rodents. Their list appears in Prakash (1962). Fitzwater

This analysis indicates that when aridity started establishing itself in the present Indian desert, the original fauna which could not adjust to the new environment either perished or migrated and it was invaded by rodents both from the west (desert forms) and from east, and now an admixture of palaeotropical and oriental fauna is found in this desert. The endemic rodents are few in number but as it takes much more time for the evolution of a species than the estimated age of the Indian desert (4000 to 10000 years, Krishnan, 1952 and Wadia 1960), it may appear that the desert is actually much older.

XI—SUMMARY

Twelve species of rodents have been reported from the Rajasthan desert. Most of them inhabit the sandy plains, whereas a few inhabit rocky and ruderal habitat. The desert gerbils are associated with certain plant communities. The stomach contents of gerbils showed that about half their diet, all the year round, is made up of vegetative parts of plants, supplemented by seeds (postmonsoon and winter) and insects (spring and summer for *Tatera* and summer for *Meriones*). The latter species prefers grasses as food which also constitute the main fodder resource for the livestock in this region. The litter-size of rodents varies from 1 to 9. During the year, the largest number of species litter during June, which is the hottest month and with longest days. This indicates that the day-length may be one of the factors which influences the breeding period in rodents of this desert.

Among squirrels, males are twice as numerous as females. The sex ratio of desert gerbils change from year to year.

The average annual number of desert gerbils varied from 31 to 458 per 90×90 m experimental plots in the three bioclimatic regions of the desert. The numbers of merion gerbils were found to be related to soil characteristics, the population being less in clayey and compact soils. An inverse relationship between grass cover and population density was also observed.

The home ranges of three species of rodents are discussed.

The rodents are behaviourally adapted to desert condition, by shifting the timings of their diurnal activity. Fossorial habit is also advantageous to them since burrows are cooler than the outside environment.

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SOME GRASSHOPPERS AND LOCUSTS OF RAJASTHAN

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I—Introduction

Rajasthan agriculture is subject to the depredations of several locusts and grasshoppers of which a few have gained notoriety. The following note outlines some salient features of those which either cause heavy loss to crops or are encountered in marked numbers in the field.

The locusts found in Rajasthan are the Desert Locust, the Migratory Locust, the Bombay Locust and the Tree Locust. The grasshoppers commonly found are the Senegalese Grasshopper, the Surface Grasshopper, the *Phadka* Grasshopper, the *Ak* Grasshopper, the Buzzing Grasshopper and the Green Tobacco Grasshopper.

II—Locusts

1. The Desert Locust, Schistocerca gregaria *(Forsk.)*

This old enemy poses a constant threat to agriculture over 30 million sq km in 60 countries of the world, from west Africa to India. Its massive attacks come in cycles. During the 1926-31 cycle the loss estimated to crops in India due to this pest was Rs 100 million (Pruthi, 1950) and in 1949-53, 20 millions (Kohli, 1963). Over the last 100 years we have had six cycles, their duration varying from 5 to 7 years. The last cycle occured between 1959-1963, and a new one appears to be starting in 1968.

It is a voracious feeder and eats its own weight of food daily. Its swarms can be as large as 400 sq miles, a normal swarm being 40 sq miles. An adult locust weighs *c* 2.5 gms and a sq mile swarm requires more than 300 tons of food daily as the number of individuals in it would be about 100-200 million.

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Discussion

Dr. S. Johnson : What do you think are the prospects of devising a successful method of biological control of rodents ?

Dr. I Prakash : We do not know the rodents well enough to introduce biological control at this stage

Dr H S Nama : *Meriones* changes its eating habit. Does it depend upon the things available at the particular time ?

Dr. I Prakash : Change of habit is dependent mainly on the availability of food.

Dr. M L Gupta How do you locate active burrows ?

Dr. I. Prakash : Pugmarks indicate live and active burrows. The mouths of inactive burrows are plugged by spider webs and they remain plugged. In order to find out if burrows are active, they are plugged at night or in the evening, and in the morning they are examined to see how many of them had been opened during the night to determine the active burrows.

Dr. S. Khera : Would you recommend that the chemical treatment you have suggested in your talk as your final verdict for control of these rodents ?

Dr I. Prakash : Yes Under natural conditions, there is an increase in the rodent population after the monsoon. The decrease starts after winter and continues through summer.

Dr. S. Khera : Is increase in population a limiting factor by itself for population ?

Dr. I. Prakash : This was not studied.

Dr. M.L. Roonwal : If the conditions were optimum, the population will not rise beyond a certain maximum.

Dr. M L. Roonwal Is there a sudden increase of population, i.e., development of population plagues, in gerbils as is known in the Norwegian lemmings ?

Dr. I Prakash : There is no record of such rise of population and its fluctuation in Rajasthan

about 6 months. In India, the swarms come from the west in April-August and breeding occurs during July-November. Sometimes spring breeding may occur as in the Punjab (1945, 1951 and 1956). The swarms then move away to the west with the easterly south-easterly winds from October-November onwards.

Control : The following are the principal methods : (i) Eggs (in subsoil) : Long-lasting insecticides, e.g. dieldrin, aldrin, are sprayed over the egg-laid ground. When hatchlings reach the surface, the poisons act on them by contact and kill them. (ii) Hoppers and adults : Hopper bands are driven to previously dug trenches where they are burried and killed *en masse*. They are also killed by poison baits. Insecticides, e.g. benzene hexachloride, aldrin, dieldrin, malathion, parathion, are either dusted or sprayed with the help of hand-dusters, hand-sprayers or petrol-operated machines against hopper hands (and adults). Large scale compaigns (against both hoppers and swarms of adults) employ aeroplanes which spray the insecticides over vast areas. Special spraying machinery, such as micronnaires, is employed in serial spraying; it disperses uniformally as little as an ounce of poison per acre and the aeroplane can cover an area as 150 sq kms in a day. In the 1962 campaign in India 4590 tons of BHC 10% dust and 18,200 litres dieldrin were used in Rajasthan by the Locust Warning Organisation.

The work of Desert Locust control in the 'scheduled desert areas' of India is being done by the Locust Warning and Control Organisation of the Central Government with its field Headquarters at Jodhpur and with the collaboration of the State Governments of Rajasthan, Gujarat, Punjab and Haryana. This organisation, which employs about 350 people on regular basis, maintains 30-55 Locust Outposts which regularly survey the whole scheduled area to assess the rise and fall of locust populations and take up suitable control measures when the situation warrants. There are more than 200 power machine units, 10,000 hand-dusting units and 200 vehicles, and adequate staff and insecticides are kept ready for combat. In times of necessity a couple of Beaver Aircraft also reach the trouble spot for aerial reconnaissance or spraying. Field research problems on Locust ecology, behaviour and control are investigated at the Field Station for Investigations on Locusts situated at Bikaner.

It exists in two phases, the differences between which are given below :—

Ph. gregaria	*Ph. solitaria*
Pronotum wide, median carina hardly perceptible in the anterior part, posterior angle broadly rounded	Pronotum narrower, median carina distinct in the anterior part, posterior angle slightly rounded
Hoppers yellow or orange, with heavy dark or yellow pattern	Green entirely, with a few dark markings
Adults with E/F ratios above 2 15 (E, Elytra, F, Femur)	E/F 2 05
Mean number of the eggs per pod 80 (60 common)	90 (120 common)
Adults short-lived	Long-lived
Development of hopper quick	Slow
Hoppers march in bands	No bands
Travel as much as 12 km a day	A few metres a day
Adults do not fly by night normally	Also fly by night

Life-history : Eggs are laid in moist sandy soil, 8-15 cms, deep. The number of eggs may vary from 17 to 157 (average 80). An average female lays 3 times at intervals of a week, i.e. about 250 eggs are laid. In summer the eggs hatch within 2 weeks and in winter in 3-4 weeks. The young hoppers that emerge out shed their skin once every 8-7 days as they grow and they undergo 5 such moults after which they are adults. The hopper period in summer lasts about 4 weeks; in winter it is prolonged, depending on the air temperature. A pair of locust if given favourable conditions for breeding can produce as many as 480,000,000 individuals as its direct-line offsprings in a year of 4 generations. However, various adverse climatic factors, natural enemies inherent disabilities, etc., check its development at every stage. An adult locust lives for about 2 months on an average during summer and about 5 months in winter.

Breeding and migration : There are two regions of seasonal breeding : (i) Spring breeding region : Breeding takes place in the first half of the year, as in north-west Africa, west Pakistan and south-east Africa, where there are winter or spring rains. (ii) Summer breeding region : Breeding occurs in the second half of the year, as in Senegal, western Africa to the Sudan, Ethiopia, southern Arabia, Pakistan and India, where summer rains are received.

Young swarms developed in one breeding region migrate down wind to the other. Thus, each region gets cleared of the swarms for

3. *The Bombay Locust,* Patanga succincta *L.*

The Bombay Locust inflicts a great deal of damage to vegetations and crops. It has a wide geographical distribution, having been recorded from India, Ceylone, Indonesia, Malaya and Thailand.

In India its plagues were recorded in 1835-45, 1864-66, 1878-84, 1901-08, 1960-62 and 1967, resulting in heavy damage to crops (Lefroy 1906, Rao, 1941; Harish Chandra and Venkatesh, 1967). Scattered individuals were observed between 1933-38. Again in 1956, they appeared in some pockets in the Barmer District (Rajasthan) and were observed in these areas upto 1962 (a maximum population of 15,197 per sq km was recorded in 1960). During the monsoon of 1960, some concentrated breeding occurred in the Khandwa District (Madhya Pradesh), necessitating control operations. From January 1966 onwards adults have again been occassionally found in the desert areas of Rajasthan. Concentrated breeding have occurred in the Agathi Island (Laccadives) since 1960, where insecticidal control measures were adopted (Menon, 1967).

Seasonal migration : Swarms get concentrated in the forests of the Western Ghats in the region of Belgaum, Goa and Kanara from November to February, when they undertake only short local flights. In March, they move southward to Mysore, Hyderabad, Madras and sometime even to Bihar and Bengal. Some also fly north-east to north Maharashtra and Gujarat. In May, scattered individuals return to the Ghat forests and lay eggs in open grasslands on the commencement of rains in June-July. Hoppers emerge in July-August and fledge in September-October.

Life-history : Unlike the other two locusts, there is a diapause in the adult stage. According to laboratory studies at Bikaner, egg-laying occurs in June. Egg-pods are laid in moist clayey soil. The maximum number of egg-pods laid by a female is four, and in all 606 eggs are laid. Normally the number of eggs per pod is 21-204. The incubation period is 30-40 days (average 33 days) at a temperature (at 10 cm depth) of 25.5-35°C.

In most cases hoppers pass through 7 instars, but sometimes 8 or 9, and in a few cases 6 instars, only. The larval period is shorter in the case of hoppers reared crowded than in those reared singly, the average minimum and the average maximum being 42 and 111 days

2. *The Migratory Locust*, Locusta migratoria *L.*

The Migratory Locust is also met with in two phases whose differentiating characters are given below :

Ph. gregaria : Pronotum saddle-shaped; median carina in profile staight or slightly concave; anterior margin rounded; posterior margin abtuse. Hind-femora shorter in relation to tegmina. Hind-tibia yellowish.

Ph. solitaria : Pronotum without constriction; median carina roof-shaped; anterior margin angular; posterior margin rightangled. Hind-femora longer than half the tegmina. Hind-tibia usually red.

Swarms were observed in 1878 in Madras (Cotes, 1891; Rao, 1948) and Bangalore in 1954 (Rao, 1954). In 1937, concentrated breeding occurred in Rajasthan and Gujarat. Between 1938 and 1956 isolated locusts were observed in Rajasthan. In 1956, concentrated breeding on a small scale took place at a few places in Rajasthan and in the adjoining parts of Gujarat. Again, in 1959 there was concentrated breeding in Gujarat and Rajasthan (Barmer District) resulting in a large population. Scattered individuals were observed in the above States thereafter.

The species is found in Europe, Africa (south of sahara), Pakistan, India, East Asia, Australia and Newzealand.

Life-history : Laboratory breeding was done at Bikaner. Eggs were laid in pods with 24-110 eggs each. The incubation period lasted 17.5-23.7 days at soil moisture ranging from 8 to 16%. At an average room temperature of 32.9°C the larval period was 40 days, and at 26.9°C 59 days. In isolated adults, the precopulation period was 30 days, and in crowded ones 20 days. Adults are of two colours, green or brown, depending on high or low relative humidity under which they were bred.

Seasonal migration : It breeds during spring in Baluchistan and the resultant adults migrate into Rajasthan and Gujarat as individuals and further multiply there during summer.

Control : Except for the sporadic concentrated breeding mentioned above, there has been no outbreaks of this locust in recent years and no large scale campaigns have been conducted in India. However, all the control measures adopted for the Desert Locust hold good for this pest.

Control : Dusting with 10% BHC (at 10-15 kg/acre) or drift spraying with dieldrin (at 2-4 oz/acre) has been found very efficacious.

2. *The Rice Grasshopper*, Heiroglyphus banian

Together with *H. nigrorepletus*, it is a serious pest of the *Kharif* crops in Rajasthan (Pruthi, 1949), causing a damage of about six million rupees.

3. *The Phadka Grasshopper*, Hieroglyphus nigrorepletus

Life-history : Eggs are laid in September and October, in clusters along the sides of *bunds* and mounds at a depth of 2-5 inches, usually inbetween the roots of various shrubs. A female on an average lays 4 egg-pods each with 20-30 eggs, (the minimum and maximum being 3 and 6 respectively). The pods are earth-coloured, oblong (1.78-0.94 cm). The eggs are not arranged in a particular order with pod, but the pod is completely filled with eggs. The average length and breadth of an egg is 5.5 and 1 mm, respectively. Hatching of eggs is governed by moisture, soil and season. The eggs in a pod can remain viable upto three years. In good rainfall areas, hatching takes place within 2-3 weeks. At 20°C nymphs do not emerge. The maximum emergence takes place at 30°C, but the emergence is quicker at 40°C. Chilling of egg-pods is helpful in breaking the diapause of one year old egg-pods. The total nymphal period is 71 days at 26-35°C. As they grow, the hoppers undergo 6-8 moults. There is only one generation in a year.

The insect occurs in two forms : a short-winged or micropterous form which is unable to fly, and the normal-winged or macropterous form.

Control : BHC and chlordane dusts applied on the surface of the soil in which the egg-pods are laid are effective in killing the nymphs hatched (Pradhan and Peswani, 1961); 10% BHC or 10% chlordane (cf. 10 kg/acre) have given very good results.

4. *The Surface Grasshoppers*, Chrotogonus *spp.*

These are common in summer, attacking seedlings of cotton (Sohi, 1964), sugarcane, maize, wheat, *bajri* and other crops in Punjab and Rajasthan. Often the attack is so heavy that crops have to be resown (Cotes, 1894; Lefroy, 1906). They are abundant during monsoon

respectively; in an abnormal case it was 195 days. Hoppers do not form bands inspite of their occurring in sufficiently large numbers in a locality.

Control : The same insecticides as used for Desert Locust are suitable for this species. In operations in the Laccadives in 1967, dusting with BHC 10% dust (applied at 15 kg per acre), and spraying with deildrin W.P. and endrin E.C. (applied at 0.25% and 0.03% concentration at 60-80 gallons per acre) gave an overall mortality of 80-90 per cent.

4. *The Tree Locust,* Anacridium rubrispinum *Bey-Bienko*

Though named a "locust", this large species does not occur in large crowds. It is common in Rajasthan (Venkatesh and Bhatia, 1966). Little is known about it. No reports of its doing any serious damage to crops are on record.

III—Grasshoppers

1. *Oedaleus senegalensis* Krauss (Khar tiddi, Rajasthan)

It has suddenly attained status of a pest during the last few years. Its swarming was first noticed in Rajasthan in 1962 (Bhatia and Ahluwalia, 1962), though it is known as a pest in several countries of Asia and Africa. In Rajasthan, it causes serious losses to *bajri* crop year after year since 1962, and campaigns have to be organised in several districts. The species is geophilus and mainly graminivorous and causes severe damage to *Pannisetum*, millet and young cotton (Joyce, 1952).

Life-history : Eggs are laid in light soils at a depth of 4-5 cm. They undergo a long diapause of several months which is broken by the onset of the rains. The average nymphal period is 24 days for the 5 instars. Hoppers usually form concentrated patches rather than long bands. The adults move in close aggregation and fly with the wind at a height of 2-10 metres. They mainly eat young *bajri* and sometimes *Tribulus*.

An interesting aspect of the pest is that when it occurs in good numbers, it can induce gregariousness to the solitarious Desert Locust that may be found in its association (Singh and Bhatia, 1965). This feature has necessitated the adoption of control measures against *Oedaleus* at par with the Desert Locust.

7. *Atractomorpha crenulata* Fab.

It is widely distributed and attacks tobacco, millets, paddy, brinjal, amaranthus, arrowroot, cabbage, cauliflower, cotton, sugarcane, wheat, opium and castor (Agrawal, 1955).

Life-history : Females lay 20-30 eggs each 1-5 days after mating. They are laid 3-4 inches deep in soil and are covered up by a frothy secretion. The egg-laying period is from February to November. The total number of eggs laid varies from 64-136, and each female may lay 3 to 6 egg pods; oviposition may last 11-17 days. Eggs are rice-shaped and 4 mm long. The incubation period is 15-66 days, depending upon soil temperature.

Nymphs undergo 5 moults. The first instar is 0.2 cm long, the 5th 1.7 cm. The duration of the nymphal stage may vary from 31 to 69 days, depending on the temperature. The adult female lives 30-68 days, the male 26-36 days. The insect shows colour dimorphism—one form being green, the other grey, in both sexes.

8. *Acrida exaltata* Walk.

This is often found in the fields in Rajasthan, but there is no record of any serious damage caused by it.

9. *Other Grasshoppers*

Other grasshoppers noticed occasionally in the desert areas of Rajasthan are : *Trusalis* sp., *Cyrtocantharris tatarica*, *Hateracris* spp., *Catantops* sp. and *Oxya* sp.

IV—ACKNOWLEDGEMENT

I am indebted to Dr. Sardar Singh, Plant Protection Adviser to the Government of India, for his guidance in the preparation of this article and for helpful criticism.

V—SUMMARY

Some of the grasshoppers and locusts commonly occurring in great numbers or causing damage to crops in Rajasthan are described. Notes on their distribution, salient features of their life-history, bionomics and

and the population dwindles in winter. In Rajasthan during 1967 areas of Pali and Ajmer districts were infested, necessitating control measures.

Life-history : Eggs are laid in clusters in soil at depth of 3-6 mm and hatch in 15 days in summer and 150 days in winter. The pre-oviposition period may be as long as 80 days during winter (4 days in summer). During spring, the average incubation period is 49 days in the laboratory at Bikaner and varies from 18-51 days. The nymphs have 5-7 instars. The optimum conditions of temperature and humidity appear to be : 25-30°C and 70% relative humidity. The number of generations varies from 2-6 in a year, depending on climate.

Control : *Baiting* : 0.3% BHC or 0.1% aldrin gave good results. *Dusting* : The main method of control is by BHC 10% dusting (at 10 kg/acre), and is most effective. Chlordane 10% or aldrin 1% dust (at 10 kg/acre) has also been successfully used.

5. *The Ak Grasshopper*, Poekilocerus pictus *Fb.*

This is a colourful grasshopper which eats one of the most distasteful plant 'ak' (*Calotropis* spp.)

Life-history : About 180 eggs are laid by a female in the soil in early May. Emergence takes place in early September and the incubation period is about 3 months under semi-natural condition. There are 6 hopper stages; the larval period is 2-8 months. Moulting is delayed during winter and no moulting has been observed during January-February. Oviposition beings 20-26 days after the final moult. There is only one generation in a year.

Control : In the absence of its original food plant (*Calotropis* sp.) in Delhi, damaged crops included brinjal, tomato, castor, etc.; it is also a minor pest on fig in South India. The insect has never reached alarming numbers. However, experimental trials with 8 oz of sodium arsenate per 100 gallons water spray have given a good kill.

6. *Sphingonotus* sp.

This is another commonly met with grasshopper in the gravel waste-lands of Rajasthan. It makes a buzzing noise during flight. Details of its biology and binomics, etc. are lacking.

BIOMETRY OF DESERT LOCUST SAMPLES FROM THIN POPULATIONS COLLECTED IN THE SUMMER OF 1968 AROUND JODHPUR

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(With 2 Tables)

I—INTRODUCTION

After the 1962-63 locust plague there was a comparative lull in locust swarming situation in the Far Eastern Region of the Desert Locust belt comprising Iran, Pakistan, Afganistan and India, and from February to May 1968, the Rajasthan desert was reported to be practically free of the locust. However, in the second fortnight of June and early July of 1968 a sudden and marked rise in population was reported simultaneously from several localities in Rajasthan and Gujrat, which created a stir, expressing fears that the recession in the locust cycle has ended and a new swarming cycle was building.

The present study was undertaken to assess the true nature of the swarming on the basis of the now well-known, Roonwal's three hypotheses (1945). Subsequent to undertaking the present study, several swarms appeared in Pakistan and India in the middle of July and early August, confirming that a new locust swarming cycle had begun.

II—DATA

A random collection of 223 specimens of the locust was made around Jodhpur from thin populations (less than 400 per sq km) of initial migrants. The origin of these swarming populations could be traced to southern Iran and Kulanch valley of Mekran in Baluchistan, where large concentrations of the adults and hoppers were reported from late February to June 1968, causing gregarisation on a vast scale. Many of these specimens carried red mites on their body, indicating their origin from places where rains had fallen.

control are furnished. A few grasshoppers that have not assumed any economic significance are also mentioned.

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Another criterion for sensing the danger of impending phase change is by watching out the sex-ratios in the 6- and 7-eye-striped field populations of the *solitaria phase*, keeping an eye on the changes they undergo as the phase starts to swing. The typical situation in the *solitaria phase* is the numerical superiority of the males among the six-eye-striped population and the otherway about in the seven-eye-striped population. Roonwal's Second Hypothesis predicts danger if the numerical male superiority among the 6-eye-striped population starts falling below 60%, tending towards parity of the sexes, which is the *phase gregaria* norm. Applying the criteria of sex-ratios on the random samples collected during the summer of 1968 we find from Table 1 that the males predominate (65.8% $\pm$S.E. 3.4) in the 6-eye-striped population and females (75.8% $\pm$S.E. 7.5) predominate in the 7-eye-striped population. Considering the S.E. of 3.4%, the preponderance of the males in the 6-eye-striped population is only slightly above the danger mark of 60%, i.e. still within the *solitaria phase* range. Compared with similar proportion of males in the 1949 sample collected from Kakoo (Bikaner) by the author (Misra, 1952), which, like the present case, also formed the initial year of a new swarming cycle, the numerical superiority of the males in the 1949 population (54.0 $\pm$ 3) had fallen well below the danger mark and was very close to parity, considering the S.E. of 3%.

Thus, while, according to the First Hypothesis of Roonwal, the locust sample of the summer of 1968 has actually crossed the danger mark (6-eye-striped population 85.2% $\pm$ 2.40) of 80%, according to the Second Hypothesis, the sample is still within the *solitaria* range, although close to the danger mark. Sex-ratio changes are rather abrupt and, therefore, are not as sensitive guides as the proportions of 6-eye-striped individuals as a whole (Nair, 1952).

Roonwal's Third Hypothesis has no real practical value in predicting a change from *phase solitaria* to the *phase gregaria* because it is only a combination of the first two hypotheses. Thus, while the First Hypothesis deals with the eye-stripe composition for the two sexes combined, showing a tendency for all locust individuals to have 6-eye-stripes, the Second Hypothesis takes into account the sex-ratios tending to reach a parity of the two sexes, the Third Hypothesis relies on the proportions of males : females of the 6-eye-striped variety out of the total number of males and females of both the eye-striped varieties combined. The danger mark, according to the Third Hypothesis, is reached

A study was made of the eye-stripe composition, the sex ratios and the distribution of the six and seven eye-stripped individuals among the total males and females, which are the bases of Roonwal's three hypotheses forecasting the danger of phase transformation in the field.

III—DISCUSSION

Analysing the sample on the basis of the eye-stripes, it will be seen from Table 1, that the six-eye-striped individuals (85.2% ± S.E. 2.40) dominated numerically over the 7-eye-striped ones (14.8% ± S.E. 2.40), crossing the danger mark of 80% by a narrow margin.

Table 1.—Sex-ratios and proportion of 6- and 7-eye-striped Desert Locust individuals in the early migrants around Jodhpur during the late June and early July 1968

Eye-stripe category	Sex-distribution and Percentage ± S E			Percentage among eye-stripe category ± S E.
	Males	Females	Total	
6-striped	125 (65 8% ± 3 4)	64 (34 2% ± 3.4)	189	85.2 ± 2.40
7-striped	8 (24 2% ± 7 5)	25 (75 8% ± 7 5)	33	14 8 ± 2.40
Total	133	89	222	

Abbreviations—S E, Standard Error = $1/n \sqrt{x(1-x/n)}$, where 100 n is population and x, a sample from that population.

For the sake of making some sort of a quantitative estimate of the dresent locust situation, it will be interesting to compare the present figures with those obtained from the collections made by the author at Kakko (Bikaner) in July 1949, which had actually initiated a new swarming cycle then. In 1949, the six-eye-striped individuals were 94.0% S.E. ± 1.4 and the seven-eye-striped ones were only 5.6% S.E. ± 1.4, showing that the six-eye-striped individuals in that year were already tending to be cent per cent in number. According to Roonwal's First Hypothesis, based on the preponderance of six-eye-striped individuals tending to be cent per cent in number in the midst of a swarming cycle, the danger of phase transformation in the present year is only marginal and much less quantitatively than it was in the year 1949.

IV—SUMMARY

From what seemed the end of the recession period of the Desert Locust (*Schistocerca gregaria* Forskal), in the late June and early July of 1968, 223 specimens of the locusts were collected around Jodhpur from thin population (less than 400 per km) of initial migrants, perhaps forming the first year of a new cycle.

Study was made of the eye-stripe composition, the sex ratios and the distribution of the two eye-striped individuals amongst the total males and females, which are the bases of the Roonwal's three hypotheses (1945) for warning the danger of phase transformation in the field.

Regarding sex-ratios, the males predominated (65.8% ± S.E. 3.4) in the 6-eye-striped population and the females (75.8% ± S.E. 7.5) in the 7-eye-striped one. Considering the S.E. of 3.4%, the preponderance of the males in the 6-eye-striped population is only slightly above the danger mark of 60%.

Of the total number of 133 males and 89 females, the 6-eye-striped males form 93.98% ± S.E. 2.6 and the females 72.22% ± S.E. 1.5 of the collection, the males crossing the danger mark of 90% by a narrow margin and the females staying within the safe margin of 78%.

From all the three criteria, it is clear that the recession period has apparently come to a close and phase transformation to *gregaria* phase has begun in a weak manner during the summer of 1968.

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when the 6-eye-striped male : female ratio rises above 90 : 78, tending to be cent per cent.

Table 2.—Proportion of males or females of an eye-stripe category out of the total number of males or females collected irrespective of their eye-stripe consideration. The collection was made of the Desert Locust early migrants around Jodhpur during the late June and early July 1968

Populations divided on the basis of sexes	No. and percentage of 6- and 7-eye-striped locust ± S E		Total no. of individuals of one sex
	6-striped	7-striped	
Males	125 (93.98%±2.6)	8 (6.02%±2.6)	133
Females	64 (72.22%±1.5)	25 (27.78%±1.5)	89
Total	189	33	222

Abbreviations—*S E*, Standard Error $= 1/n \sqrt{x(1-x/n)}$, where 100 n is population and x a sample from that population.

The data of the 1968 summer collection has been arranged in Table 2 which shows that the 6-eye-striped males are 93.98% ± S.E. 2.6 out of the total of 133 males of the two varieties of eye-striped individuals pooled together. The females are 72.22% ± S.E. 1.5. While the percentage of 6-eye-striped males in this sample has crossed the danger mark of 90%, the females are still within the *solitaria* range. Here again lack of sensitivity is because of the sex-ratio changes being rather abrupt. Comparable figures for the 1949 collection made by the author (1952) are 6-eye-striped males 97.55% out of a total of 140 males of 6-and 7-eye-striped individuals collected and 90.55% females out of the total of 127 females. These show a tendency towards cent per cent males and females having 6-eye-stripes.

Biometry of the body parts of this sample is under study and will be published elsewhere. But from all the three embodied in Roonwal's three hypotheses, it is clear that the recession period has apparently come to a close and the phase transformation to *gregaria phase* has begun in a much weaker manner than it had during the 1949-50 (Misra, 1952).

Prof. S.D. Misra : It would mostly depend on rainfall. The Desert Locust swarms move northward from east Africa to Egypt and Persia which have winter rainfall. Some swarms move north east to southern coast of Arabia and both these groups build up their numbers and move east to Afganistan, Baluchistan, Pakistan and western parts of India where monsoon rains occur. The intensification of the phase change will depend upon whether conditions of rainfall present favourable conditions for the locust to build up their population and the anti-locust organization in the different countries fail to maintain their channel of communications, giving prior information to the neighbouring countries about the swarm movements. The whole chain of events is closely watched and the information collected at Anti-Locust Centre in London is interpreted and passed on. In the past year the rainfall in the monsoon areas of western parts has been very meagre and the anti-locust organisations have kept close contacts by a net-work of wireless stations. The chances for the Desert Locust developing into a plague seem rather dim, but it will depend on rains.

Discussion

Dr. H S. Nama : Can the ensuing of cycle be forecast from eye-stripes on locusts bred in the laboratory ?

Prof S D. Misra : The discovery of existence of two main types of eye-striped individuals of the Desert Locust was made by a young locust entomologist, Roonwal, in 1936. While he was working in Mekran (Baluchistan), he made very careful observations on the eye-stripes and sex ratios of *phase solitaria* specimens collected by him and by others in the field during 1932-35, 1936 and 1937, which were the non-swarming periods of the Desert Locust. In 1945, he published his result in the *Bull ent. Res* London, correlating the changing composition of eye-stripes and sex-ratios, on the basis of which a new swarming cycle could be predicted.

Dr M L Gupta : What is the practical value of these hypotheses which involve counting of eye-stripes and noting of down of sexes? The field-men employed will not be able to see and note these morphological details easily.

Prof S D. Misra No, this difficulty is imaginary. Eye-stripes can be seen and counted easily with a hand-lens. Distinguishing the sexes is even easier. These are the only two things which have to be noted down and recorded on a label to be pinned with the specimen A regular collection of the locust has to be made in the outbreak areas with all these data, which should form an essential part of the reports sent out.

Dr H S. Nama But my point remains unanswered. Would the data on eye stripes and sex-ratios from the laboratory-reared locust be able to forecast a new swarming cycle ?

Prof S D Misra : Oh, no The laboratory conditions are different from those of the field In the laboratory we test the various factors, like temperature, humidity, food, effect of crowding and so on, one by one. Laboratory data must be correlated with observations in the field. The practical use of Dr. Roonwal's hypotheses is only for field-collected random samples.

Dr. S Khera : What exactly happens during transformation of phases ? Does one phase die out or is it a transformation of the same individuals or within the same generation ?

Prof S.D. Misra Transformation occurs if hoppers are crowded or isolated. Prof Faure, way back in 1932, demonstrated this very convincingly in his laboratory rearing experiments at the University of Pretoria in South Africa. If young hoppers from a swarm are isolated and reared in cages singly, they would lose their characteristic pigment patches in the next moult and turn out to be *solitaria* phase adults in the same generation. In nature, this situation is created from crowded or isolated egg-layings in the previous generation.

Dr S. Khera Are the two phases intraspecific varieties ?

Prof. S D. Misra . Yes, they are.

Dr. S. Johnson : Is there any physiological difference between the 6-striped and 7-striped individuals ?

Prof. S D. Misra Yes, some. We find an increase of pigment and metabolic activity as the *solitaria* phase passes into the *gregaria* phase. A lot of work has been done in the past decade on physiological differences and their significance.

Dr. P.D. Gupta : Is there any information about whether the seventh eye-stripe disappears or the individuals with seven stripes die out in a population ?

Prof S D Misra : Individuals with seven-eye-stripes die out as the population moves towards *gregaria* phase.

Prof. K.S. Kushwaha : What are the chances of the second year of the new swarming cycle, begun in this summer (1968), to develop into a menace next year ? In view of your statement, that a new swarming cycle has begun weakly, is it likely that this might intensify and we may have a locust plague ?

THE LOCUST PROBLEM IN RAJASTHAN

By

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Abstract

The Desert Locust prefers arid and semi-arid regions, and the Rajasthan desert is well suited as one of its permanent homes. During recessions between plagues it lives as scattered individuals in the solitary phase. Under favourable rainfall conditions, there is a mass and crowded multiplication and the population is transformed into the gregarious phase, giving rise to incipient swarms. Periodic invasion of swarms and outbreaks of locust plagues have been regular features of the Rajasthan desert. There is a regular exchange of swarms between the winter and summer breeding areas. Even solitary populations migrate from one region to the other.

Locust control is mainly a Government responsibility. For this purpose a permanent Central Locust Organization is maintained to keep watch over the desert areas for any locust developments and undertake control measures where necessary. Locust swarms have enormous powers of migration, hence presence of swarms in any one country in the desert locust belt is a threat to other countries though they may be thousands of miles away from the source of invasion. To ensure the success of anti-locust campaigns as a whole, international co-operation is essential. The Food and Agricultural Organization of the United Nations has played an important role in this direction. India has been actively participating in these efforts.

With the development of powerful insecticides and advances in application techniques, anti-locust campaigns are now much more effective. The conventional methods of locust control in Rajasthan by trenching, burning and beating have, to a large extent, been replaced by the chemical methods.

recently by Roonwal and Bose (1964). Thus, we now have a reasonably adequate idea of the species occuring in the region and their distribution.

Rajasthan has a land area of *c.* 342,274 sq. km. (132,077 sq. miles) and a population of *c.* 20 million. The diagonally running (SW-NE) Aravalli Range cuts the land in two unequal and climatically different halves. The large north-western portion, *c.* 4/5ths of the area, forms a part of the Great Indian Desert, while the small south-eastern tract is rocky but well wooded due to adequate rainfall. This difference has an important bearing on the termite fauna. The dry half has a fauna with palaearctic and ethiopian affinities, while the wet half has oriental affinities.

Economically, termites cause enormous damage to crops, plantations, forest nurseries, fruit trees and wood-work in buildings, although precise figures are not available. The belief that dry areas may be comparatively free is not true. Numerous houses in Jodhpur and vicinity are infested, and the problem concerns not merely householders but also the Army and Air Force authorities whose buildings and ordnance stores get attacked.

In October 1966, the Jodhpur University National Cadet Corps had a taste of termites in the Training Camp at Nagaur, about 130 km. north-east of Jodhpur. The camp was held in the Cattle Fair Ground which is entirely sandy. On arrival the cadets sprinkled the ground with a little water to settle the sand and spread their beddings and slept soundly. Next day when they rolled up the beddings for the morning inspection, they found to their horror that hundreds of the beddings had been extensively eaten up by termites during the night, leaving large gaping holes in almost each one. Irrigating the ground with BHC (benzene hexachloride) prevented further damage. The culprit species was *Odontotermes obesus* which was abundant in the soil and was attracted to the surface during the night in hundreds of thousands by moisture and food.

Another example from an arid area is worth mentioning. Some years ago, as reported by Roonwal (1955), the town of Sri Hargobindpur (Gurdaspur District, Punjab) and nearby townships were virtually ruined due to the constructional timber of houses being severely attacked by the termite *Heterotermes indicola*. The town, founded about the year 1662, was free from attack for nearly 280 years, but from 1940 onwards termite damage started occuring, and by 1952 the town was heavily

Anacanthotermes macrocephalus is the largest termite and has foraging habits. It lives in extensive underground galleries and forms small (*c.* 60-150 mm high and 100-150 mm in basal diameter), conical hills of loose granular earth above ground. The soldiers and workers come out daily in foraging parties and cut and take back grass leaves and seeds to their underground chambers.

Psammotermes rajasthanicus (Text-fig. 1) is confined to the arid western area, and the soldier is trimorphic, there being major, medium and minor forms varying in body-size, the build of the mandibles and in other respects. *Speculitermes cyclops* is of interest as the soldier form in the genus is extremely rare, and no soldier has hitherto been found in Rajasthan.

The species which cause the greatest amount of destruction to wood-work are *Heterotermes indicola* and *Coptotermes heimi* both of which thrive in dry wood, although they have ground connections as well. *Odontotermes obesus* is particularly active during the rains and attacks moist wood and other household articles of a cellulosic nature such as paper, books, clothes, windows, doors, stored timber, etc., as well as certain crops. The extensive damage it caused overnight to hundreds of beddings spread on the ground in a camp has been mentioned above. Species of *Microtermes* infest the roots of millets and other crops. Potentially, all species of termites are pests of crops and also a danger to all kinds of wood-work.

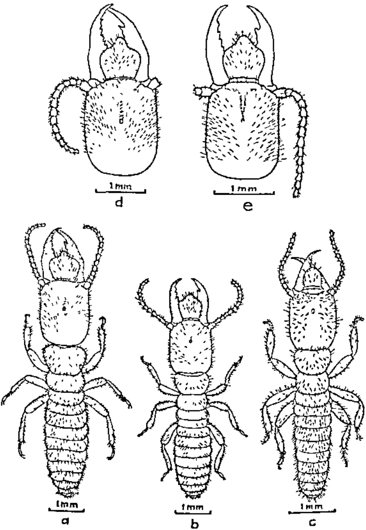
The biology of none of the species is known, and we have here a virgin field for those who may wish to carry out research work which would be rewarding in more ways than one. The social habits of termites and their polymorphism (there are three major castes, viz. soldiers, workers and reproductives), behaviour, physiology (wood digestion, etc.) and, finally, their great economic importance, make this group of insects a worthy subject for close attention. Termites envolved their complex social structure in the mesozic times, millions of years before man appeared on earth.

III—SUMMARY

As a result of work done during the last few years, the termite fauna of Rajasthan, which was practically unknown, is now known fairly adequately, and 19 species and subspecies have been found. They

17. *Microtermes mycophagus* (Desneux)
18. *Trinervitermes biformis* (Wasmann)
19. *Trinervitermes heimi* (Wasmann)

Two of these species have formed the subject of detailed morphological studies, namely, *Anacanthotermes macrocephalus* (Gupta, 1962a, b) and *Odontotermes obesus* (Kushwaha, 1960c, d).



Text-fig. 1—Three types of soldiers in *Psammotermes rajasthanicus* R. & B. from Rajasthan, in dorsal view. Soldiers major *(a, d)*, medium *(b, e)* and minor *(c)*. *(From* Roonwal & Bose.) Not to same scale.

belong to three families (Hodotermitidae, Rhinotermitidae and Termitidae) and the following 12 genera, each with a single species or subspecies except where otherwise mentioned : *Anacanthotermes*, *Psammotermes*, *Heterotermes*, *Coptotermes*, *Speculitermes*, *Amitermes*, *Synhamitermes Eremotermes* (2), *Microcerotermes* (3), *Odontotermes* (3), *Microtermes* (2) and *Trinervitermes*(2).

Economically, termites cause extensive damage. *Anacanthotermes macrocephalus* is a harvesting termite and gathers grass. *Heterotermes indicola* and *Coptotermes heimi* are highly destructive to wood work in houses. *Odontotermes obesus* destroys cellulosic materials, e.g., paper, books, clothes, wood-work, etc., especially in the rainy season. The last mentioned and other species of *Odontotermes*, as well as species of *Microtermes*, etc., attack millets and other crops. Sugarcane is also attacked by termites. Virtually nothing is known of the biology, behaviour, physiology, ecology and social habits of Rajasthan termites, and these insects would form a very profitable subject of research.

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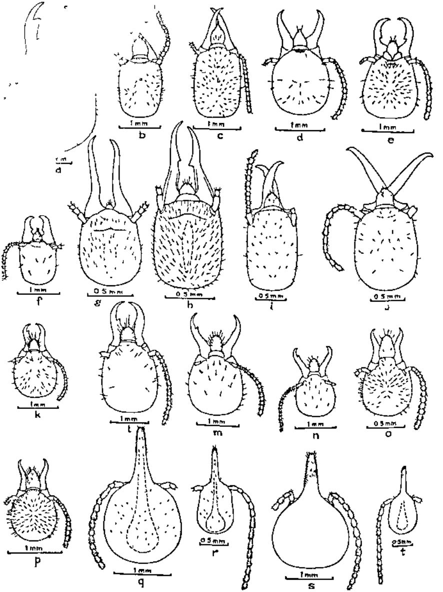
Discussion

Dr. S.D. Misra : Where does the mouth open in *Nasutiterms* ?

Dr. M.L. Roonwal : Only the front part of the head is enlarged and the mouth is situated on the lower side at the base of the enlargement

Heads of soldiers of Rajasthan termites, in dorsal view. (*Adapted from* Roonwal & Bose.)

(a) *Anacanthotermes macrocephalus* (Desn). (b) *Psammotermes rajasthanicus* R. & B., soldier minor. (c) *Heterotermes indicola* (Wasm.). (d) *Coptotermes heimi* (Wasm.). (e) *Amitermes belli* (Desn.). (f) *Synhamitermes quadriceps* (Wasm.). (g) *Eremotermes neoparadoxalis* Ahm. (h) *Eremotermes paradoxalis* Holmg. (i) *Microcerotermes championi raja* R. & B. (j) *Microcerotermes tenuignathus laxmi* R. & B. (k) *Odontotermes bellahunisensis guptai* R. & B. (l) *Odontotermes brunneus kushwahai* R. & B. (m) *Odontotermes obesus* (Ramb), large soldier. (n) Ditto, small soldier. (o) *Microtermes obesi* Holmg. (syn. *anandi* Holmg) (p) *Microtermes mycophagus* (Desn). (q) *Trinervitermes biformis* (Wasm.), soldier major. (r) Ditto, soldier minor. (s) *Trinervitermes heimi* (Wasm.), soldier major. (t) Ditto, soldier minor.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SEASONAL INCIDENCE OF INSECT PESTS ON COTTON IN RAJASTHAN

By

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(With 1 Text-figure)

I—Introduction

Cotton is a major crop grown in Rajasthan (acerage of 278103 hectares, production 167127 bales annually)*. The crop is attacked by a large number of insect pests which cause annual loss of 10-20 per cent. For evolving a successful insecticidal schedule it is essential to observe the sequence, time of appearance, intensity and duration of infestation of the different pests at different stages of crop-growth.

II—Material and Methods

Studies were carried out at the Agronomy Farm Udaipur, during 1966-67. The cotton variety C-Indore 1 was sown on July 16, 1966 in 4 rows of plots 80 ft × 8 ft. The population count of the different pests was made at weekly intervals. The sampling was done in accordance with the recommendations of the Indian Central Cotton Committee. Five plants were selected at random from each row and 3 leaves (6th, 7th and 8th from top) selected on these plants were used for actual counts of aphids (*Aphis gossypii* Glov.), jassids (*Empoasca devastans* Distant), thrips (*Thrips tabaci* Lind.) and white flies (*Bemisia tabaci* Genn.). Other insect pests except bollworms were counted as they appeared on these five plants. For bollworms, the method used by Pradhan and Menon (1945) was followed. All the sheded buds, flowers and bolls from under the 5 plants were collected and examined for larvae. The bolls were cut into slices and after differentiating the larvae into spotted bollworm (*Earias* spp.) and pink bollworm (*Platydera gossypiella* Saund.), their number was recorded separately.

*Data for 1964-65, from Rajasthan Agriculture Diary, 1963.

No more seen from January onwards. High incidence might be probably due to slight late sowing as reported by Balsubraymanyam and Iyengar (1950). Further, high incidence may also be interpreted as due to high rainfall in September whence the population build-up started. This is in agreement with findings of Afzal and Ghani (1953) who correlated high incidence with high rainfall in Punjab.

3. Thrips (*Thrips tabaci* Lind.) : Attack started from August last week (same recorded by Khan and Rao, 1960, in Marathwara). No significant rise in population till September end, whence immediate build-up started and reached peak in October 3rd week. Pest continued in small numbers till December end after which it was no more seen.

4. Cotton whitefly (*Bemisia tabaci* Genn.) : First observed at September end. Build-up of population started soon onwards, reaching peak by October end. Pest no more seen on plants from December onwards. Low incidence might be due to slight late sowing of crop as reported by Husain and Trehan (1933).

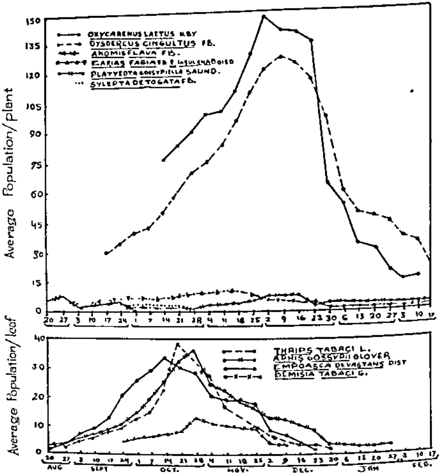
5. Green semilooper (*Anomis flava* Fab.) : Is a sporadic and minor pest. Observed quite early in season (August) when its population was maximum after which there was a decline. No more seen from October onwards. Thus it seems to remain active only during rainy season.

6. Cotton leaf-roller (*Sylepta derogata* Fabr.) : Is a sporadic pest (but reported as major pest from many parts of India). During current season observed only as minor pest. Incidence started at August end, thereafter there was no appreciable increase in population onwards. Almost became obscure by last week of October.

7. Spotted bollworm (*Earias* spp.) : First made their appearance in September second week, and soon increased in numbers, reaching at the peak in second week of November. Population seen at low ebb during December to February (same also observed by Nangpal, 1948). Decline in population by close of December (also reported by Khan and Rao, 1960).

8. Pink bollworm (*Platyedra gossypiella* Saund.) : First observed infesting crop in October. Population low in first week but soon started rising, reaching peak in December last week, but never reached very high.

9. Red cotton bugs (*Dysdercus cingulatus* Fabr.) : First made their appearance in September 3rd week. Population soon started rising,



Text-fig. 1—Seasonal incidence of insect pests of cotton at Udaipur during 1966-67.

III—Results and Discussion

1. Aphids (*Aphis gossypii* Glov.) : First appears on crop in August. Maintained its population almost throughout growing season till harvest in February. Number less during August, September, December and February than in rest of the period. Maximum population recorded in last week of October.

2. Jassids (*Empoasca devastans* Distant) : Also made their appearance on crop along with aphids at August end. Population started increasing onwards, finally reaching peak in October 2nd week, thereafter declining.

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reaching peak during mid-December and then declining. Pest observed on crop till harvest, though in small numbers.

10. Dusky cotton bugs (*Oxycaraenus laetus* Kirby) : Showed quite high incidence. First observed infesting crop in October 2nd week and immediately there was a rapid build up of population, reaching peak in December after which there was a sharp fall though the incidence continued till harvest.

In general, the incidence of aphids, jassids, thrips, whiteflies, red cotton bugs and dusky cotton bugs was fairly high, while that of green semilooper, cotton leaf roller, spotted bollworms and pink bollworms was comparatively low.

IV—ACKNOWLEDGEMENTS

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V—SUMMARY

The cotton crop in Rajasthan is infested by a large number of insect pests which cause an annual loss of 10-20%. Studies on seasonal incidence of insect pests were carried out during 1966-67 at Udaipur. The population estimation of pests was made at weekly intervals. Aphids (*Aphis gossypii* Glov.), jassids (*Empoasca devastans* Distant), thrips (*Thrips tabaci* Lind.) green semilooper (*Anomis flava* Fabr.) and cotton leaf roller (*Sylepta derogata* Fabr.) make their appearance in August, the population reaches a peak during last, 2nd and 3rd weeks of October and last week of August respectively. Cotton whiteflies (*Bemisia tabaci* Genn.), spotted bollworms (*Earias* spp.) and red cotton bugs (*Dysdercus cingulatus* Fabr.) appear in September 3rd week and the population reaches a peak during October end, November 2nd week and mid-December respectively. The incidence of pink bollworms (*Platyedra gossypiella* Saund.) and dusky cotton bugs (*Oxycarenus laetus* Kriby) starts from October, reaching the maximum in December last week. The incidence of aphids, jassids, thrips, whiteflies, red cotton bugs and dusky cotton bugs was fairly high while that of green semilooper, cotton leaf roller, spotted bollworms and pink bollworms was comparatively low.

A REVIEW OF PROGRESS IN STUDIES ON FORAGE AND PASTURE INSECT PESTS OF RAJASTHAN

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(With 3 Tables)

I—Introduction

Protection technology in India has proved decisive in 'green revolution' but in the wake of the so-called 'white revolution', more dynamic multilateral management for enhancing yield and quality not only of food and fibre but also of the forage, including grasses, is imminent. For placing the economy of vast arid and desert zones of north-western Rajasthan on more sound footing, farming has to be restricted and integrated with cattle-rearing and sheep-raising. To meet out the immediate needs of the country, the present production of 800 q has to be raised to 3,000 q of green fodder per hectare per year with an average of 12-15% protein content, besides an increase in the cultivated area from 4.4% to about 12%. Further, the production in grasslands and pastures—within and outside forest area—must increase by 500% with 10-12% protein content. It is, therefore, inevitable to rehabilitate and systematically manage our natural pasture or grasslands by upgrading, controlled grazing, and simultaneously increasing the fodder cultivation in rotation with food crops. Such a programme conforms with soil conservation, and helps in development of fodder resources to support our well developed livestock sector. Pest management studies pertaining to forage and pasture have been made since 1961 in Udaipur district as a step in this direction. They were initiated under an I.C.A.R. scheme *(Investigations on Forage and Pasture insects)* and have been continued subsequently.

Kushwaha and Jain (1962, 1966) listed 61 species of forage insects (including some predators and parasites) belonging to 58 genera, 27 families and 8 orders (Coleoptera, Diptera, Hemiptera, Isoptera,

wriggles out with the abdominal tip thrust out first; complete emergence takes 20-35 minutes; there are six larval instars and the full grown larva appears golden yellow with brownish specklings dorsally while pale yellow hue dorso-laterally and ventrally.

It takes 26.5 days on an average when reared on lucerne (takes 21.08 and 26.98 days on Bermuda grass and maize respectively); spins a faint yellow fusiform cocoon in about 2.45 hours on an average; pupa *obtect* type, hairy and measures *ca.* 15.0 mm long and 4.5 mm broad; pupal period 5.3 days (5.7 and 5.8 days when larvae reared on Bermuda grass and maize respectively). While testing food-preference it was noted that the Bermuda grass was preferred most, next was maize and the least lucerne (as based on larval weight gain). Total life-cycle was completed in 41.39 days on lucerne (34.4 and 40.8 days on Bermuda grass and maize respectively) during August-November.

A thachinid fly, *Carcellia buitenzorgiensis* Bar. (Diptera : Tachinidae) parasitized about 8-20% of the caterpillars collected from the field during August-September; maggots generally enter the host body through the VIII and IX abdominal segments dorso-laterally and the spot of entry is visible as a puncture with fluid oozed out. However, the parasitized larva continues feeding and dies in prepupal stage soon after spinning the cocoon web. Maggots are reddish, muscoid, cylindrical, tapering anteriorly and indistinctly segmented; measure *ca.* 10-12 mm long and 1.5-2.5 mm broad (Singh and Kushwaha, 1971).

Another group of hairy caterpillars belonging to family Arctiidae and resembling those of Lymantriidae, is represented in this region by some pests known for their notoriety.

(3) Lucerne hairy caterpillar, *Creatonotus gangis* Linnaeus (Arctiidae : Lepidoptera). The pest was recorded for the first time in Rajasthan damaging lucerne, Bermuda grass, Johnson grass (*Sorghum halepense* (L.) Pers.) and a weed *Withania somnifera* (Kushwaha *et al.*, 1964, 1966), although reported earlier elsewhere (Hampson, 1901, 1905; Lefroy, 1909; Sevastopulo, 1948).

Baser and Kushwaha (1968) have studied the detailed biology and external morphology of this pest. It is a sporadic pest of lucerne, infesting it during July-November; the moths appear about middle of July; males and females measure *ca.* 16.5 mm and 16.5 mm long, and 38.0 mm and 42.5 mm across spread wings respectively.

Hymenoptera, Lepidoptera, Orthoptera and Thysanoptera), recorded from Udaipur district; the seasonal occurrence and peak period of their damaging activities were briefly discussed. Subsequently, Kushwaha, Sharma and Bhardwaj (1964), listed 39 pests infesting forage and pastures around Udaipur.

II—PESTS OF LUCERNE OR ALFALFA (*Medicago sativa* LINNAEUS)

1. Defoliators or Foliage Nibblers infesting during Kharif

(1) Tussock caterpillars, *Euproctis* spp. (Lymantriidae : Lepidoptera). Kushwaha and Bhardwaj (1967) studied the detailed biology and external morphology of *E. virguncula* Walker, *E. subnotata* Walker, *E. lunata* Walker and *E. variens* Walker recorded around Udaipur since 1960 (Kushwaha and Jain, 1962, 1966). Of these *E. virguncula* is the commonest and a major pest infesting from June to February, with peak period of incidence during August-September. *E. subnotata* is equally serious from September to February, particularly during October-November, and simultaneously attacks with *E. virguncula*. The remaining two species are only minor pests. *E. lunata* was observed during September-January while *E. variens* during August-September. Besides direct damage the caterpillars cause considerable annoyance to the feeding cattle because of their thick coat of hairs reported to be irritating and poisonous (Lefroy, 1909).

(2) Yellow hairy caterpillar, *Psalis pennatula* Fabricius (Lymantriidae : Lepidoptera). It is another important polyphagous pest seriously infesting lucerne around Udaipur (Kushwaha, *et al.* 1962, 1964) from early August till middle November, but the peak period of infestation has been observed from the last weak of September upto end of October.

Singh (1966), and Singh and Kushwaha (1970) have studied its detailed biology and external morphology. The moths are nocturnal, sluggish and take to small flights. Moths do not copulate in captivity; eggs are invariably laid on the underside of the leaf in clusters of 10-35 in netted pattern of 3-5 rows and covered with froth; a single female lays 50-80 eggs; eggs are smooth, spherical with the micropyle end depressed and carrying an orange speck, *ca.* 0.892 mm in dia.; incubation period 5-7 days during August-October and 8-10 days during November-December. The young larva cuts an irregular hole, nibbles the egg shell and

Cutworms (Noctuidae) comprise the most notorious group of polyphagous pests devastating a wide range of crop plants, including forage; 11 species belonging to 5 genera, viz., *Agrotis*, *Cirphis*, *Laphygma*, *Prodenia* and *Spodoptera*, have been commonly reported from different localities throughout India. The species observed infesting lucerne in Rajasthan include *Agrotis spinifera* Hubner, *Laphygma exigua* Hubner, *Prodenia litura* Fabricius, *Cirphis* (=*Leucania*) *unipuncta* Haworth and *Spodoptera mauritia acronyctoides*. Guen.

(5) *Agrotis spinifera* Hubner (Noctuidae : Lepidoptera). It is a serious pest of lucerne during February—March and was earlier reported infesting various crops in Rajasthan (Kushwaha and Jain, 1962, 1966; Srivastava and Khan, 1962). Pareek and Kushwaha (1971) have studied the detailed biology, control and morphology (of the caterpillar). Moths are active, with short flights, nocturnal, hiding in crevices or under clods in fields during day; females measure *ca.* 14.9 mm long and 35.2 mm across wings, while males are 13.2 mm long and 28.1 mm across wings.

Moths generally copulate during early hours and lay eggs singly as well as in batches of 3-16, arranged in two rows covered with fluffy mass, preferably on the under-surface of the leaves, twigs etc.; an individual laid 96-254 eggs upto 4 days when fasting, but on feeding 2% sucrose solution it laid 296-1422 eggs and continued for 4-9 days; fresh eggs creamy white, round, measuring *ca.* 0.648-0.700 mm, sculptured with longitudinal ridges; more eggs laid during September-October than during March-April; preoviposition period 2 days and post-oviposition 1 day; incubation 4-5 days during July-August and 7-11 days during February-March; while hatching, the head emerges out first and the entire larva is extricated by contraction movements within 15-20 minutes. There are six larval instars; the full-grown larva is 13-segmented and brownish to ash grey. Larval period takes 26.27, 35.15 and 36.12 days (*av.*) on maize, lucerne and cowpea respectively,

Larva stops feeding a day or two before pupation, and pupates in an earthen cell 3-4 inches under soil; pupa of *obtect* type, cremaster comprises of 2 pairs of spines on the X segment; pupal period varies from 14 to 18 days (*av.* 16.2 days) when larvae reared on lucerne (10-15 days on maize, 19-25 days on cowpea) during August-October, and 15-20 days (*av.* 17.3 days) during February-April (16-24 days on berseem). The life-cycle takes 42-64 days.

Moths start pairing within three hours of their emergence and copulate tail to tail for 2-5 hours; pre- and post-oviposition periods were *ca.* 17 and 24 hours respectively; about 160-317 eggs laid during night in clusters of rows but an individual female lays about 285-695 for 2-3 days (45-70% eggs laid on the first day); each egg is round, pale cream yellow, shining and measures *ca.* 0.75 mm in diameter (*av.* of 40); hatch in 4-5 days and the individual larva is extricated from the egg within 20 minutes; there are seven larval instars and the larval period was 27-32 days on lucerne and 22-24 days on Bermuda grass during July-October when three generations were completed. The young larva is whitish with large dark head; subsequently it becomes straw coloured and developes a dorsal yellowish longitudinal streak. Pupa *obtect* type; pupal period varies from 5-7 days in case of larvae reared on Bermuda grass and 7-10 days in those reared on lucerne; fully developed pupa measures *ca.* 13-17 mm long and 3-6 mm broad. Entire life-cycle is completed within 31-37 days (*av.* 33.8) on Bermuda grass and 38-49 days (*av.* 42.0) on lucerne.

(4) The hairy caterpillar, *Amsacta lineola* Fabricius (Arctiidae : Lepidoptera). First reported from this region as a major pest infesting lucerne, cowpea, maize etc. during July-November, but peak period of its incidence observed from middle of September to middle of October (Kushwaha *et al.*, 1964). Bhardwaj and Kushwaha (1967) have studied the detailed biology, external morphology and chemical control.

Moths lay 160-450 eggs singly or in batches after 24-30 hours pre-oviposition, on under surface of foliage; appear pale yellow, round with somewhat granular shining surface, *ca.* 0.873 mm in dia.; incubation 3-5 days; larva emerges out through an irregular exit hole and feeds on egg shell itself; there are six instars, each measuring 2.70 mm, 4.65 mm, 7.75 mm, 16.82 mm, 19.67 mm and 30.80 mm serially. Full-grown larva is dark with tufts of hairs.

When reared on various foods under laboratory conditions, the larval period was 15-19 days on lucerne, 12-19 days on maize, 20-22 days on cowpea, 20-23 days on *jowar*, 24-28 days on groundnut and 25-32 days on cotton. Larvae pupate within a rough cocoon made out of silk, hairs and leaves but also made of earth; prepupal stage 1-2 days; pupa dark brown, *obtect* type, pupal period 8-12 days. Two generations were completed before hibernation in pupal stage. Total life-cycle was completed within 27-43 days on different food plants.

region (Kushwaha *et al.*, 1964, 1966). *Plusia nigrisigna* Walker (Noctuidae : Lepidoptera)—Betala and Kushwaha (1965) have studied the detailed biology and external morphology of this cabbage semilooper, seriously infesting lucerne besides cabbage, cauliflower, berseem, cowpea and gram during June-October and January-March. The moths laid 76-183 eggs (*av.* 93) singly scattered irregularly, for 2-7 hours generally during night or early morning hours; they are round, *ca.* 0.48 mm in diameter, creamy white and sculptured with longitudinal ridges; hatch in 4-5 days (*av.* 4.25) with 88.2 per cent hatchability on an average; the caterpillar cuts an irregular circular exit and emerges out in 15-35 minutes; 74.7% larval mortality was observed on account of bacterial pathogenicity during the III and IV instar in August-September; there are five larval instars with total larval period 20.80 days (*av.*) when larvae reared on lucerne (18-25 days, *av.* 21.19 when reared on cowpea); prepupal stage 2-3 days; pupa *obtect* type, developed within a whitish cocoon; and pupal period was 6-9 days (*av.* 7.29) when the respective larvae were reared on lucerne (5-8 days, *av.* 6.68, on cowpea); life-cycle was completed in 32.36 days (*av.*) on lucerne under laboratory conditions during July-October (29-35 days, *av.* 31.69 on cowpea).

Plusia orichalcea Fabricius (Noctuidae). Major pest of lucerne besides berseem, cabbage, cauliflower and cowpea, etc., during January-September with peak period of incidence February-March. Life-cycle takes (*av.*) 38.13 days under laboratory conditions.

Xanthodes albago Fabricius (Noctuidae) has been occasionally observed infesting lucerne during July-September.

A few butterflies have been observed as minor pests :

Rice skipper, *Pelopidas mathias* Fabricius (=*Baoris mathias* Fabricius) (Hesperiidae : Lepidoptera) observed infesting during June-September.

Common grass yellow, *Terias hecabe* (Linnaeus) (Pieridae : Lepidoptera) during July-September.

Catochrysops sp. (Lycaenidae : Lepidoptera) occasionally infests lucerne during June-July, and pea during February-March.

(8) In addition to the lepidopteran pests (*vide supra*), some beetles, grasshoppers and the sawfly are also responsible for considerable damage to lucerne. These are :

Lucerne weevil, *Hypera variabilis* (Herbst.) (=*H. postica* (Gyllenhal) (Curculionidae : Coleoptera).—Srivastava (1959), and Kushwaha and Jain (1962, 1963, 1966) recorded the pest from Rajasthan seriously

(6) Lucerne caterpillar, *Laphygma exigua* Hubner (Noctuidae : Lepidoptera). It is a major pest of lucerne infesting during April-September, and was reported earlier from Rajasthan (Srivastava, 1959; Kushwaha, *et al.* 1964, 1966) and elsewhere (Ayyar, 1940; Kadam and Patel, 1956; Sen Gupta and Behura, 1957; Lal and Narayanan, 1961; Sohi, 1964; Dutta, 1964); moths are pale ochraceous brown, measuring *ca.* 2.9 cm across spread wings; forewings have pale spots marginally and the hindwings are white semi-hyaline; nocturnal, total life-cycle is completed within about 25-29 days under laboratory conditions. Srivastava (1959) observed food preference for potato (*Solanum tuberosum* L.), pea (*Pisum sativum* L.), lucerne, and berseem which supported better growth than linseed (*Linum usitatissimum* L.), tomato (*Lycopersicon esculentum* Mill.) and brinjal (*Solanum melongena* L.).

(7) Other noctuids observed damaging lucerne are minor pests : Armyworm, *Pseudaletia separata* Walk. [syn. *Cirphis* (=*Leucania*) *unipuncta* Haworth] (Noctuidae). Wide-spread damage is prevalent throughout Rajasthan during June-October with period of high incidence from August to middle of October. Life-cycle is completed in about 31.15 days (*av.*) under laboratory conditions.

Tobacco caterpillar, *Prodenia litura* Fabricius (Noctuidae). The pest was observed earlier infesting castor (*Ricinus communis* Linnaeus), tobacco (*Nicotiana tabacum* Linnaeus), tomato (*Lycopersicon esculentum* Mill.), brinjal (*Solanum melongena* Linnaeus), cabbage (*Brassica oleracea* L. var. *capitata* L.), cauliflower (*Brassica oleracea* L. var. *botrytis* L.), pea (*Pisum sativum* Linnaeus) and lotus besides lucerne in Rajasthan (Kushwaha *et al.*, 1964); the incidence has been noticed during June-November locally. Entire life cycle is completed in about 4-5 weeks.

Swarming caterpillar, *Spodoptera mauritia acronyctoides* Guen. (Noctuidae). Observed infesting during July-October; Life cycle is completed in about a month, 2 or 3 generations occur during period of incidence. Reported to infest *jowar* and other host plants elsewhere (Kadam *et al.*, 1956).

Another noctuid, gram caterpillar (*Heliothis armigera* Hubner, syn. *Chloridea obsoleta* Fabricius) is a regular pest of gram but equally serious to lucerne from January to July. Life cycle is completed in 34.21 days (*av.*). Already recorded damaging a number of crop plants (Ayyar, 1940; Kadam and Patel, 1956; Kushwaha *et al.*, 1964, 1966).

Two species of *Plusia* have been recorded more commonly in this

Mustard sawfly, *Athalia proxima* Klug. (Tenthredinidae : Hymenoptera). Minor pest during October-December.

2. *Sap Sucking Insects infesting during Kharif*

The tree hoppers or membracids, locally called 'Ramjee-ki-gaya', have been commonly observed damaging in large numbers a wide range of crop plants, including forage, besides forest trees, shrubs, grasses, weeds etc. in this region. Besides direct feeding on plant sap, they cause considerable damage by egg-laying in the plant tissue. Two species, viz., *Tricentrus bicolor* Distant and *Leptocentrus obliquis* Walker, were reported from Rajasthan earlier (Kushwaha and Jain, 1962, 1966). *T. bicolor* has been studied in details (Sankhla, 1966; Sankhla and Kushwaha, 1969).

(1) *Tricentrus bicolor* Distant (Membracidae : Hemiptera). Is a serious pest of lucerne and berseem throughout the year, but peak period of incidence observed during September-October; population counts were made fortnightly in lucerne crop by 100 net-sweepings regularly from January-December, in 1965, and the monthly population data were subjected to multiple correlation with mean monthly data of temperature and humidity; consequently, it was revealed that the population in this case is significantly correlated with the temperature, but no significant correlation occurs between the population and humidity individually or in combination with the temperature. Copulation has been commonly observed during March-October; male mounts the female and pairing continues in head to head position; following copulation, the female cuts a longitudinal slit through the bark with the help of its ovipositor which comprises of six valvifers; the eggs are embedded within the bark of tender branches singly or in groups of 5 to 6, eggs measure *ca.* 0.13 mm long and 0.015 mm broad; incubation period varies from 8-13 days during September-October. The young nymph moults 5 times within 33-55 days under the laboratory conditions; the nymphs are sedentary and complete their entire development while feeding on one and the same plant; the hoppers are gregarious.

Insecticidal trials with emulsifiable concentrates of lindane (0.1%), malathion (0.025%) and phosphamidon (0.02%) showed that all insecticides used did reduce the pest population significantly.

(2) *Leptocentrus obliquis* Walker. It is a minor pest on lucerne from October-June, and on berseem during February-June.

infesting from January to March, though already reported elsewhere damaging lucerne, 'sengi' (Indian clover, *Melilotus parviflora*), pea, *Pyrus indica* and *P. malus* (Lefroy, 1909; Fletcher, 1917, 1920; Rao, 1921; Rahman, 1940 and Beeson, 1941). Pradhan *et al.*, (1960) have shown dieldrin (EC) to be most effective (61.51 times more toxic than p-p' DDT) against grubs. Maximum infestation was observed during March with an average of *ca.* 153 grubs per 4 sq. ft. area of the crop or 181 grubs per 100 plants as based on plant counts; it was commonly observed that the grub population suddenly decreases about middle of March. Consequently, it may be possible that the pest be avoided to a considerable extent if the cuttings of the crop during this season, *i.e.*, January-March, were taken at shorter intervals of about a month or less, preferably within the first week of every month, and the crop cut very close to the ground. On an average, the larval and pupal periods take about 24 and 20 days respectively during January-February (mean temp. ranges 3.84°—26.72°C) and 12 and 7 days during March (mean temp. ranges 11.79°—29.13°C) under laboratory conditions. The life cycle takes 38.83 days (*av.*).

Grey weevil, *Myllocerus maculosus* Desb. (Curculionidae : Coleoptera). Mild infestation was observed during August-September.

Red pumpkin beetle, *Aulacophora foveicollis* (Lucas) (= *abdominalis* Fabricius) (Chrysomelidae : Coleoptera).—Major pest on lucerne from beginning of March to middle of August; adults bite holes and grubs bore into roots.

Oxya ebneri Willemse (Acridiidae : Orthoptera). Minor pest of lucerne during April-July (serious to Bermuda grass and maize). Gupta and Kushwaha (1965, 1968) have studied the detailed biology and external morphology of this pest (*vide* below, Pests of Bermuda grass).

Atractomorpha crenulata (Fabricius) (Acridiidae : Orthoptera). Major pest of lucerne during November-June particularly June (*vide* Pests of pastures).

Chrotogonus sp. (Acridiidae : Orthoptera). Minor pest of lucerne during June-July (*vide* Pests of pastures).

Hieroglyphus nigrorepletus Bol. (Acridiidae : Orthoptera). Minor pest during November-December.

Phaneroptera gracilis Burm. (Acridiidae : Orthoptera). Minor pest during November-June.

Table 1.—Pest fauna of lucerne during rabi

Incidence	*Peak Period*	*Species*
		(a) Defoliators
June-November	—	*Prodenia litura* Fabricius (Agrotinae : Noctuidae)
June-February	(Aug.-Sept.)	*Euproctis virguncula* Walker (Lymantriidae)
July-May	(February-March)	*Agrotis spinifera* Hubner (Agrotinae : Noctuidae)
July-November	—	*Creatonotus gangis* Linnaeus (Arctiinae : Arctiidae)
August-November	(October)	*Psalis pennatula* Fabricius (Lymantriidae)
September-January	—	*Euproctis lunata* Walker (Lymantriidae)
September-February	(Oct.-Nov.)	*Euproctis subnotata* Walker (Lymantriidae)
October-December	—	*Athalia proxima* Klug. (Tenthredinidae)
November-December	—	*Hieroglyphus nigrorepletus* Bol. (Acrididae)
November-June	(June)	*Atractomorpha crenulata* (Fabricius) (Acridiidae)
	—	*Phaneroptera gracilis* Burm. (Acridiidae)
January-July	—	*Heliothis armigera* Hubner (Agrotinae : Noctuidae)
January-March	—	*Hypera variabilis* Herbst. (Curculionidae)
January-March and June-November	—	*Plusia nigrisigna* Walker (Plusiinae : Noctuidae)
January-September	(February-March)	*Plusia orichalcea* Fabricius (Plusiinae : Noctuidae)
March-September	—	*Laphygma exigua* Hubner (Agrotinae : Noctuidae)
		(b) Sap sucking
Throughout the year	(Sept.-October)	*Tricentrus bicolor* Distant (Membracidae)
	—	*Piezodorus rubrofasciatus* Fabricius (Pentatominae : Pentatomidae)
October-June	—	*Leptocentrus obliquis* Walker (Membracidae)
October-December and March-July	—	*Dysdercus cingulatus* Fabricius (Pyrrhocorinae : Pyrrhocoridae)
November July	—	*Nezara viridula* Linnaeus (Pentatominae; Pentatomidae)
	—	*Nezara viridula* var. *smaragdula* Fabricius
November-July	—	*Craptostethus servus* (Fabricius) (Lygaeidae)
November December and March-April	—	*Dolycoris indicus* Stal. (Pentatominae : Pentatomidae)
November-December and July-August	—	*Aspongopus janus* Fabricius (Dinidorinae : Pentatomidae)
January-February	—	*Aphis craccivora* Koch. (Aphididae)
January-April	(March)	*Bagrada cruciferarum* Kirk. (Pentatominae : Pentatomidae)
March-April	—	*Andrallus spinidens* (Fabricius) (Asopinae : Pentatomidae)
March-June	—	*Antestiopsis cruciata* (Fabricius) (Pentatominae : Pentatomidae)

(3) A few Pentatomids (Hemiptera) have been observed infesting in large numbers : *Piezodorus rubrofasciatus* Fabricius. Major pest of lucerne throughout the year; occasionlly infests berseem and 'metha'. *Nezara viridula* Linnaeus and *N. viridula* var. *smaragdula* Fabricius. Minor pest infesting from November up to July. The life cycle is completed in 63.78 days (*av.*). *Aspongopus janus* Fabricius. Minor pest of lucerne from July to August and November to December. *Antestiopsis cruciata* (Fabricius). Minor pest during March-June.

(4) Other bugs occasionally noticed damaging include a Lygaeid and a Pyrrhocorid : *Graptostethus servus* (Fabricius) (Lygaeidae). Incidence starts in November and maximum population is built up during June-July after which there is sudden decline; it is also a minor pest on berseem during March-May. *Dysdercus cingulatus* Fabricius (Pyrrhocoridae). Incidence starts from second week of March to second week of July and again from last week of October to second week of December but maximum population is built up during June-July. Mild infestation was noticeable in berseem fields during May-June.

(5) The spotted alfalfa aphid, *Therioaphis maculata* (Buckton) is a major pest during February-June. Pareek and Kushwaha (1970) have studied the biology and reported that phosphamidon (0 03%) proved most effective but malathion (0.15%) is safe and almost equally effective.

3. *Defoliators or Foliage Nibblers infesting during Rabi*

Since most of the pests discussed under *kharif* continue their damaging activities during *rabi* season also, a mere list of pests indicating the period of their incidence during this season is provided to help in drawing up an integrated pest control schedule for the entire year (Table 1).

Amin *et al.* (1970) studied malathion residues on lucerne and in milk. The initial deposit 36.80 ppm for the dose 0 45 kg/ha dissipated to 8 ppm level during October, while during March it (40.93) disintegrated to 5 ppm after 48 hrs. In case of 1.12 kg./ha the initial deposit reached below 8 ppm after 4 days during October and March, and 6 days during December. But 3 ppm level was reached after 4 days for lower conc. during October, 3 days during March and 6 days during December. For higher conc. it reached after 4, 6 and 10 days during March, October and December respectively.

sheath and reach the central shoot producing 'dead heart' and resulting in stunted growth; characteristically, the tillering starts from base but the plant may be killed in severe infestation. Jain and Bhatnagar (1962) have studied the varietal resistance in the various strains of *jowar*, and the correlations between the intensity of infestation and various plant characters like height, leaf number etc. under natural conditions of insect infestation.

July-November

Hieroglyphus nigrorepletus Boisd., major.

August-October

Sesamia inferens (Walker), major (*vide* Pests of maize)

September-October

Chilo partellus (Swinhoe), major (*vide* Pests of maize)

Rhopalosiphum maidis (Fitch), minor.

VI—PESTS OF MAIZE (*Zea mays* LINNAEUS)

1. *Defoliators infesting during crop season*

March-April

Heliothis armigera Hubner (= *Chloridea obsoleta* Fabricius), minor.

April-July

Cirphis (= Leucania) loreyi Dup. (Hadeninae : Noctuidae), minor. Life-cycle completed within a week.

April-September

Sesamia inferens (Walker) (Noctuidae : Lepidoptera), major. Kushwaha *et al.* (1961) studied borer incidence and estimated 10.34-17.48% infestation (*ca.* 15.52%) of the two borers in post-harvest plant counts of hybrid maize during October, 1960.

Chilo partellus (Swinhoe) (Pyralidae : Lepidoptera), major. In a control trial against the borers it was observed that Endrin EC (0.02%) and DDT 50% WP (0.25%) (each sprayed thrice, first spray in the last week of July, second in second week August, and third in last week August) reduced the borer infestation but endrin alone was really effective. To replace Endrin, three fortnightly applications of Lindane (0.05% EC followed by 1% Gr. twice) or Endosulfan (0.1% EC and 5% Gr. twice) (Gr. 14.8 kg/ha) have been recommended (Noor and Kushwaha, 1967; Chatterji, 1970).

Milk samples of the cows fed on treated fodder did not show malathion residues.

III—PESTS OF BERSEEM OR EGYPTIAN CLOVER
(*Trifolium alexandrinum* LINNAEUS)

Introduced from Egypt in 1904, it is one of the best *rabi* fodder crops of North India under adequate irrigation.

The pest fauna is given in Table 2.

Table 2.—Pest fauna of barseem

Incidence	*Species and status of the pest*
	(a) Defoliators
November-February	*Euproctis virguncula* Walker, major pest
December-January	*Euproctis lunata* Walker, minor
January-March	*Plusia nigrisigna* Walker, major.
January April	*Plusia orichalcea* Fabricius, major.
January-June	*Heliothis armigera* Hubner, major.
April-May	*Aulacophora foveicollis* (Lucas), minor.
May-June	*Oxya ebneri* Willemse, minor
	(b) Sap sucking
February-June	*Tricentrus bicolor* Distant, major.
	Leptocentrus obliquis Walker, minor.
	Piezodorus rubrofasciatus Fabricius, major.
March-April	*Andrallus spinidens* (Fabricius), minor.
March-May	*Graptostethus servus* (Fabricius), minor.
	Dolycoris indicus Stal., minor.
March-June	*Dysdercus cingulatus* Fabricius, minor.

IV—PESTS OF METHRA OR METHA (*Trigonella foenum-groecum*)

It is an important *rabi* fodder of low irrigational requirements.

February-April

Piezodorus rubrofasciatus Fabricius, major.

March-April

Aulacophora foveicollis (Lucas), minor.

V—PESTS OF JOWAR (*Sorghum vulgare* PERS.)

July-September

(i) *Spodoptera exigua* Hubner, minor.

(ii) *Atherigona varia soccata* Rond. The *jowar* shoot fly is a major pest particularly in the seedling stage in Rajasthan and Delhi. Eggs are laid singly on the leaves and the maggots after hatching enter the leaf

VII—PESTS OF COWPEA (*Vigna catjang* WALP., *V. sinensis* SAVI.)

Cowpea is a protein-rich *kharif* green fodder more resistant to drought and tolerant to heat; irrigated hot weather crop is sown in March whereas the rainfed crop is sown in June or July after monsoon commences.

June-September

Plusia orichalcea Fabricius, major.

June-October

Plusia nigrisigna Walker, major.

July-August

Acrocercops caerulea Meyrick (Gracillariidae : Lepidoptera), minor; the tiny larvae mine blotches on the leaves.

July-September

Spodoptera exigua Hubner, minor.

July-October

Amsacta lineola Fabricius, major; peak period of incidence mid-September to mid-October; takes *av.* 34.45 days to complete the life cycle under laboratory conditions.

August-September

Euproctis virguncula Walker, major.

Agrotis spinifera Hubner, minor; full grown larva measures *ca.* 23.56 mm when reared on cowpea (smaller than those reared on maize or lucerne); the percentage of larvae pupated and the adults emerged was least in this kind of larval feeding than in those fed on maize or lucerne.

August-October

Psalis pennatula Fabricius, major; a Tachinid fly, *Carcellia buitenzorgiensis* Bar. is an effective parasite.

September-October

Proxenus hugeli Feld., (Noctuidae : Lepidoptera), minor.

October-November

Anticarsia irrorata Fabricius (Noctuidae : Lepidoptera), minor.

VIII—PESTS OF GRAM (*Cicer arietinum* LINNAEUS)

Gram is generally grown as a dry crop in the *rabi* and requires low rainfall and mild cold; sown in middle of October or November.

June-July

Atractomorpha crenulata crenulata (Fabricius) (Acridiidae : Orthoptera), minor, infesting fodder maize (*vide* Pests of pasture).

July-September

Euproctis subnotata Walker (Lymantriidae : Lepidoptera), minor.

Amsacta lineola Fabricius (Arctiinae : Arctiidae), major.

Amsacta lactinea Cramer (Arctiinae : Arctiidae), major.

July-October

Spodoptera mauritia acronyctoides Guen. (Noctuidae : Lepidoptera), minor

Spodoptera exigua Hubner (Noctuidae : Lepidoptera), minor.

July-November

Oxya ebneri Willemse (Acridiidae : Orthoptera), major; life-cycle is completed in 66-70 days (*av.* 67.17).

August-September

Euproctis virguncula Walker (Lymantriidae : Lepidoptera), minor. *Amsacta moorei* Butler (Arctiinae : Arctiidae), major. *Agrotis spinifera* Hubner (Noctuidae : Lepidoptera), minor. *Laphygma exigua* Hubner (Noctuidae : Lepidoptera), major.

August-October

Psalis pennatula Fabricius (Lymantriidae : Lepidoptera), major; life-cycle is completed in 42.8 days, on an average, when larvae were reared on maize (*vide* Pests of lucerne).

Pseudaletia separata Walker (Noctuidae : Lepidoptera), major; total life-cycle takes 24-29 days.

September-October

Chrotogonus sp. (Acridiidae : Orthoptera), minor.

2 *Sap-sucking insects infesting during crop season*

March-April

Anaphothrips sudanensis (=*flavicinctus* K.) Trybom; synonyms : *alternans* Bagn. (Egypt) *medioflavus* Sch. (Ceylon), *citricinctus* Bagn. (India), *speciosus* Hood (Australia), *bicinctus* Hood (Trinidad), *transvaalensis* Faure (S. Africa). (Thripsidae : Thysanoptera), minor pest.

September-October

Rhopalosiphum (=*Aphis*) *maidis* (Fitch) (Aphididae : Hemiptera), minor.

August-September

Pseudaletia separata Walker. minor.

October-November

Anticarsia irrorata Fabricius (Noctuidae : Lepidoptera), minor.

X—PESTS OF PASTURE

To study the pasture fauna, the following four localities within Udaipur district were selected for regular field collections, population sampling and incidence :—

(i) Pastures adjoining Udaipur, *ca.* 580 m. above mean sea-level in Aravali Ranges. There is intensive agriculture cultivation amidst the vast forest environs. (ii) Pastures within Forest Game Sanctuary at Jaisamand, 64 km. south of Udaipur, *ca.* 292 m. above mean sea-level; the preserved forest has dense wild environment. (iii) Pastures adjoining Kumbhalgarh Fort, *ca.* 136 km. north-east of Udaipur; *ca.* 1088 m. above mean sea-level; comparatively a sparse forest. (iv) Pastures adjoining Mangalwar village, about 65 km. north-east of Udaipur on Udaipur-Chittor Road; has vast pasture tract with fewer forest plants.

It is broadly concluded that the population under thicker forest at Jaisamand or dense cropping vegetation at Udaipur is much lower than under the thinner forest adjoining Kumbhalgarh (Kelwara) or pasture environs at Mangalwar. Thus, localities at Jaisamand and Udaipur provide better protection to the predatory fauna on account of thick forest and cropping conditions, and the grasshopper population was thinned out consequent to greater pressure of this factor, whereas in other localities this predatory fauna was rarified for want of sufficient shelter and hence lack of enemy numbers resulting in higher grasshopper fauna.

The identified pasture fauna is briefly described below :—

Throughout year

Acrida exaltata exaltata (Walker), major. Maximum population of 9 per unit area was observed during second week of January in Kumbhalgarh (Kelwara) area; the species recorded in all the areas (*vide supra*).

Chrotogonus trachypterus (Blanch.), major; maximum population of 46 per unit area (750'×10') was observed durng third week of February in

January-February

Aphis craccivora Koch. (Aphididae : Hemiptera), minor

Plusia nigrisigna Walker, minor.

January-March

Plusia orichalcea Fabricius, minor.

January-April

Heliothis armigera Hubner, major; the gram caterpillar defoliates and bores the pods.

February-March

Agrotis spinifera Hubner, minor (*vide* Pests of lucerne).

February-April

Agrotis ypsilon Rottenberg, major; the gram cutworm seriously nibbles the foliage, cutting the branches generally at ground level; hides under dried twigs and clods during day; pupates in soil.

Laphygma exigua Hubner, minor.

IX—PESTS OF JOHNSON GRASS (*Sorghum halepense* (L.) PERS.)

Johnson grass, locally called *baru*, is a perennial graminaceous weed resembling *jowar* and infesting it and maize crop from which it is indistinguishable in early growth; contains HCN in young stage of the plant and can be fed after flowering stage.

July-September

Aegocera venulia Cramer (Agaristidae : Lepidoptera), minor.

Alphaea vittata Moore (Arctiinae : Arctiidae), minor.

Amsacta lactinea Cramer, major.

Euproctis virguncula Walker, minor.

July-October

Psalis pennatula Fabricius, major.

July-November

Creatonotus gangis Linnaeus, major.

August-September

Amsacta moorei Butler, major.

Pericallia ricini Fabricius (Arctiidae : Lepidoptera), minor. Life-cycle is completed in about a month.

August-September

Pseudaletia separata Walker. minor.

October-November

Anticarsia irrorata Fabricius (Noctuidae : Lepidoptera), minor.

X—PESTS OF PASTURE

To study the pasture fauna, the following four localities within Udaipur district were selected for regular field collections, population sampling and incidence :—

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It is broadly concluded that the population under thicker forest at Jaisamand or dense cropping vegetation at Udaipur is much lower than under the thinner forest adjoining Kumbhalgarh (Kelwara) or pasture environs at Mangalwar. Thus, localities at Jaisamand and Udaipur provide better protection to the predatory fauna on account of thick forest and cropping conditions, and the grasshopper population was thinned out consequent to greater pressure of this factor, whereas in other localities this predatory fauna was rarified for want of sufficient shelter and hence lack of enemy numbers resulting in higher grasshopper fauna.

The identified pasture fauna is briefly described below :—

Throughout year

Acrida exaltata exaltata (Walker), major. Maximum population of 9 per unit area was observed during second week of January in Kumbhalgarh (Kelwara) area; the species recorded in all the areas (*vide supra*).

Chrotogonus trachypterus (Blanch.), major; maximum population of 46 per unit area (750′ × 10′) was observed durng third week of February in

copulation lasts 4-9 hours; male abdomen is twisted down to fuse with the female to achieve coitus; an individual female oviposited twice, laying 23-29 eggs about 3-4 cm deep in coarse sandy soil; egg-pod is *ca.* 13.56 mm long and 4.38 mm in dia., comprising of 11-15 eggs; eggs are arranged obliquely vertical within each pod; each egg is cylindrical slightly curved and tapering at both ends which are rounded, and measures *ca.* 3.27 mm long and 0.708 mm in dia. (*av.* of 25); hatch in 28-40 days. Newly hatched nymphs moult five times, and the life cycle is completed in 71-81 days (*av.* 76.6) on maize, 72-83 days (*av.* 77.3) on *jowar* while 63-68 days (*av.* 65.4) on Bermuda grass. Two generations were completed during August-November and March-June.

Trilophidia annulata (Thunberg), major; maximum population of 15 per unit area was observed during the third week of May at Kelwara; an individual consumed 0.05342 g Bermuda grass, 0.0156 g maize (dry wt. of foliage), and 3.789 sq. cm. maize foliage within 24 hours. The life cycle is completed in 105, 90 and 77 days respectively on maize, cowpea and *jowar*.

March-November

Chloebora marshalli Henry, minor; maximum population of 7 per unit area was observed during the second week of September at Kumbhalgarh; the species was not observed at Jaisamand and Udaipur.

March-December

Catantops pinguis Stoal, minor; maximum population of 58 per unit area observed during second week of October in Kumbhalgarh area; an individual consumed 0.0277 g Bermuda grass, 0.03897 g maize (dry wt.), and 5.476 sq. cm. maize foliage within 24 hours.

April-Movember

Orthoctha indica Uvarov, major; maximum population of 23 per unit area was observed during first week of October in Mangalwar area.

April-February

Aulacobothrus sp., major; maximum population of 43 per unit area was observed during the third week of September in Kumbhalgarh area.

June-February

Oedaleus abruptus Thunberg, major; maximum population of 22 per

unit area was observed during the second week of October in Kumbhalgarh area.

Atractomorpha crenulata Fabricius, major; maximum population of 12 per unit area was observed during second week of September in Udaipur area; an individual consumed 0.104 g dry wt. and 5.545 sq. cm. foliar area of maize.

Euproctis virguncula Walker, minor.

Cyrtacanthacris tatarica tatarica Linnaeus, minor. Only a few specimens were collected at Kumbhalgarh and Jaisamand area.

July-August

Aegocera venulia Cramer, minor. The life cycle was completed in about 30 days.

July-September

Alphaea vittata Moore, minor.

Argina cribraria Clark, minor; moth spotted orange, *ca.* 3.2 cm across spread wings, hairy caterpillars actively defoliate.

Euproctis variens Walker, minor.

Tricentrus bicolor Distant, minor.

July-October

Pericallia ricini (Fabricius), minor.

July-November

Creatonotus gangis Linnaeus, major.

Oxya ebneri Willemse, minor. Gupta and Kushwaha (1965, 1968) have studied the detailed biology and external morphology of the grasshopper of this species. It is a common pest of Bermuda grass (*Cyanodon dactylon* (L.) Pers.) and maize (*Zea mays* Linnaeus) locally. The adults and hoppers generally abound grass strips bordering fields of sugarcane (*Saccharum officinarum* L.) and elephant grass (*Pennisetum purpureum* L.) etc. Weekly population counts were made by net sweeping method (100 sweepings) during morning (8.00-10.00 a.m.) and evening (4.00-6.00 p.m.) hours. Consequently, the average weekly incidence (adults as well as hoppers) recorded was 8.5, 11.6, 18.3, 6.6 and 3.0 during respective months from July to November; independent correlation was observed between the population incidence and temperature or humidity.

The adults abundantly copulate during August by riding mode in head to head position and continue for 35-58 minutes; the male abdomen

is twisted down to interlock with the female abdomen. An individual female oviposited upto three times, laying a maximum of 88 eggs upto 4.0 cm deep in clay loam while 5.0 cm in coarse sand; the number of eggs invariably increased in each subsequent laying. An egg pod is *ca.* 9.49 mm long and 4.46 mm in dia.; it comprises of 17-38 eggs (*av.* of 10). The eggs measure *ca.* 4.231 mm long and 1.158 mm in dia. (*av.* of 25); they hatched in 18-20 days; the newly hatched nymph moults five times and the life cycle is completed in 59-64 days (*av.* 62.24) on Bermuda grass while 66,70 days (*av.* 67.19) on maize.

July-December

Eyprepocnemis alacris impicta Uvarov, minor; it also infests maize crop adjoining pastures at Jaisamand area. Copulation was observed to last for 50-130 minutes by riding mode after which females appeared sluggish, oviposited 2-3 times after 2-4 days of copulation, and laid 43-61 eggs about 2-3 cm deep in case of coarse sandy soil; upto three egg pods were laid by a female and each pod comprised of 23-31 eggs in each; each egg measured *ca.* 16.73 mm long and 8.49 mm in dia., and hatched in 37-39 days; the newly hatched nymphs moult five times and the entire life cycle was completed in 84-98 days (*av.* 91.4 days) on Bermuda grass.

August-November

Psalis pennatula Fabricius, major.

Hieroglyphus nigrorepletus Bolivar, minor. Maximum of 8 per unit area at Jaisamand.

Cataloipus indicus Uvarov, minor; maximum population of 5 per unit area was observed during last week of August in Jaisamand area,

August-December

Chloebora crassa (Walker), major; maximum population of 52 per unit area was observed during the first week of October in Mangalwar area. An individual consumed 0.133 g maize (dry wt. of foliage), and 3.99 sq. cm. maize foliage while 8.64 sq. cm. *jowar* foliage.

September-October

Pelopidas mathias Fabricius, minor.

September-November

Gonista sp., major; maximum population of 12 per unit area was

observed during the third week of September in Mangalwar area. An individual consumed 0.0988 gm maize (dry wt. of foliage).

Oedaleus senegalensis Krauss major.

Choroedocus illustris (Walker), minor; solitary individual collected at Jaisamand.

Euconocephalus incertus (Walker), minor; a few individuals collected at Kumbhalgarh and Jaisamand area.

February-June

Eucoptacra praemorsa Stoal, minor; maximum population of 9 per unit area was observed during the last week of May in Jaisamand area.

XI—CONTROL

The *general equilibrium position* (GEP) determined by the interaction between the species and environmental factors may be temporarily altered by an extensive use of insecticides. However, initiating any control operation below the economic injury level would be unwarranted economically, and may even prove harmful to the biotic components of the ecosystem. Further, the decision to use these chemicals must be based on the range and degree of their specific selectivity for fighting a particular group of target pests, carefully sparing the non-target organisms like natural enemies and pollinator insects. Drift of insecticides to adjoining area must be avoided. Use of granular formulations (30 to 60 mesh size) reduces contamination in comparision to dusts on this account.

Chlorinated hydrocarbons on account of their highly persistent residues, accumulation in food chains, non-selectivity to beneficial insects, fish and wildlife, and insect resistance are mostly not used in the modern pest-management or integrated programme. Organo-phosphorus esters exhibit greater selective toxicity. So are the carbamates also selective in their action, getting readily degraded *in vivo* and in the environment, having low mammalian toxicity, and hence used in the integrated approach. Systemic insecticides are also considered selective because they directly affect only such injurious insects as suck juice from the treated plant or devour their tissues, except when these are consumed by the predators.

Insecticides commonly used (kg/ha) against pests in forage and pasture are : Malathion : Aphids (0.67-1.12 kg); grasshoppers, army-

worms, *Epilachna* beetles, *Lygus* bugs, leafhoppers, thrips (1.12 kg); lucerne weevil (1.12-1.40 kg).

Carbaryl : Chinch bugs (0.28 kg); grasshoppers, armyworms, cutworms, *Epilachna* beetles, alfalfa caterpillar (1.12 kg); sorghum midge (1.68 kg).

Methoxychlor : Leafhoppers (0.56 kg); alfalfa caterpillar (0.84-1.12 kg); spittle bugs (1.12 kg); lucerne weevil, *Epilachna* beetle (1.12-1.68 kg).

Mevinphos : Aphids, lucerne caterpillar (0,14 kg); grasshoppers (0.28-0.56 kg); cutworms (0.42 kg).

Trichlorfon : Lucerne caterpillar (0.28-0.35 kg); *Lygus* bug, cutworms, armyworms (1.12 kg).

Parathion : Aphids, armyworms (0.28 kg); lucerne weevil (0.28-0.56 kg).

Diazinon : Grasshoppers, aphids (0.56 kg); lucerne weevil (1.12 kg).

Azinphosmethyl : Lucerne weevil (0.56 kg).

Demeton : Aphids (0.28 kg).

Detailed description of various methods of control is being published elsewhere (Kushwaha and Bhardwaj, 1970).

XII—ACKNOWLEDGEMENTS

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XIII—SUMMARY

Pests of forage crops, viz., lucerne, berseem, *metha*, *jowar*, maize, cowpea, gram and Johnson grass, etc., have been listed, together with brief description of their bionomics including seasonal incidence, biology, status, control, etc.

Pests of pastures, their incidence and population per unit area, extent of damage etc. have been briefly described.

In all, 93 species of pests (belonging to 62 genera, 20 families and 7 orders) have been dealt with. Lepidopterans include 9 families, 23 genera and 31 species; orthopterans 2 families, 20 genera and 23 species; hemipterans 5 families, 13 genera and 13 species; coleopterans 2 families,

3 genera and 3 species; and hymenopterans, dipterans and thysanopterans one each.

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VARIETAL SUSCEPTIBILITY OF SORGHUM TO STEM BORER, *CHILO ZONELLUS* (SWINHOE), UNDER FIELD CONDITIONS

By

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I—INTRODUCTION

Rajasthan is a major *Sorghum* (jowar) producing State. The total area under cultivation is 1015.5 hectares and the production is 2,87,000 tons (1965-66). *Sorghum* is a staple food of many people and also provides fodder for animals. *Kharif* is the main grain-crop season, while the fodder-crop is generally grown in April-May with irrigation. Both the crops are severely attacked by *Chilo zonellus* Swinh. The introduction of high-yielding varieties requires an urgent study of *Chilo* as adequate information is lacking.

Pant *et al.* (1961) studied the development of freshly hatched larvae of *Chilo zonellus* on different hosts, viz., maize (*Zea mays*), bajra (*Pennnisetum typhoides*) and jowar (*Sorghum vulgare*). A relationship between per cent infestation of maize plants and borer population of *Chilo zonellus* was derived by Singh *et al.* (1962). Kalode (1964) reported maize varieties Jullunder local, Arbhavi local and Ganga hybrid 101 to be resistant, and Amrillde-Cuba, Malan, Patiala local, Ranjit and Deccan hybrids as comparatively susceptible, as worked out by the injury index. Sikka *et al.* (1957) also conducted such work on *Chilo*. Trehan and Butani (1949) also reported on the possibility of varietal variations to *Chilo zonellus* damage.

II—METHODS

A field experiment was carried out with 15 varieties of jowar during the *kharif* season (1967) on the Government Agricultural Farm,

Sumerpur. The experiment was conducted in a randomised block design. The gross plot-size was 20′×12′ and each variety was replicated four times. Sowing was done in July 1967, keeping 1½′ row to row distance and 9″ from plant to plant (by thinning). 30 kg nitrozen and 15 kg phosphate per acre was supplied to the crop. A one-tenth area was marked in each plot for the assessment of the loss caused by the borer. Observations were recorded in mid-August and in the first week of October. The percentage infestation was worked out by the ratio of total number of plants to the number of damaged plants in a unit area.

III—RESULTS AND DISCUSSION

Plant resistance was evaluated by the the external injury caused by the stem borer in the varieties studied. An assessment of external injury was made by counting dead hearts during the growth period of plants. It was observed that upto mid-August damage in all the varieties was slow and uniform. The minimum damage was 4.8% in the local variety, and maximum was 12% in CSH 2. The magnitude of difference in damage was not critical among the varieties studied. However, (9 9%, 6.0%, 6.2%, 8.5%, 10.0%, 5.3%, 10.5, 8.4%, 11.0%, 10.9%, 6.6% and 8.3% damage was recorded in CSH 1, I.S.3796, I.S.3924, I.S.2944, I.S.2031, I.S.84, I.S.511, I.S.3797, I.S.3922 (Sel. 405), I.S.815, I.S. 1601, I.S.1601B and I.S.3691 respectively.

A significant difference in the damage percentage was observed in October among jowar varieties studied. The local variety again stood lowest, with only 18.4% damage. Similarly, the maximum damage (60.9%) was observed in CSH 2. On the whole, all the varieties can be put in 5 groups on the basis of decreasing susceptibility as judged by damage percentage, thus I. Most susceptible varieties. Damage percentage 60.9-58.1%, Include varieties CSH 2, CSH 1 and I.S.84 (60.9%, 58.1% & 60.7% damage respectively). II. I.S.511 variety (52.8% damage). III. Damage 47.7% to 44.5% includes I.S.3796, I.S.2944, I.S.3797 and I.S.3922 (44.5%, 47.7%, 44.5% and 47.7% damage respectively). IV. Damage 30-32.7%, includes I.S.3924, I.S.2031, I.S.815, I.S.1601, I.S.1601B, and I.S.3691 (31.1%, 32.3%, 32.7%, 30.0%, 32.3% and 31.2% damage respectively). V. Least susceptible includes only local variety (18.4% damage).

OBSERVATIONS ON *THERETRA OLDENLANDIAE* FABRE (LEPIDOPTERA : SPHINGIDAE)

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I—Introduction

The present paper includes observations on the larvae *Theretra oldenlandiae* Fabre, in a garden.

II—Observations

The larvae were caught feeding on *Impatiens balsamina* and *Zinnia verticillata*. They are voracious foliage eaters, remaining attached on the underside of the leaf. They start feeding from the lower side of the leaf, devouring the whole leaf except the midrib which is completely left out. Only fresh leaves were consumed; when old and somewhat dry, the fresh parts only were eaten up. While feeding, the larva holds the leaf from under-rib by means of its appendages. With one hold it tries to consume as much leaf as possible by stretching its body in different directions. From the midrib upto the margin the larva bites the leaf in a semi-circular pattern. After feeding for sometime it relaxes either on the branch or on the midrib by completely stretching itself. It appears that the biting reflex is initiated soon after the closing of labial palpi on a leaf edge and the mandibles start opening and closing to cut the leaf. At this point the feeding is continued if the larvae are on the leaf, otherwise they move on to another leaf. In this way, first they ascertain, by sampling, the right food plant. Feeding occurs during night unless the larvae are starved. During daytime the larvae prefer to remain motionless on the underside of the leaf. While feeding, after finishing a leaf they proceed to another one immediately above it, hence an upward defoliation takes place. The larval faeces are small, cylindrical and black.

The larvae, when fully grown, are 3 to 4 inches long and shed their skin five times. They feed, on an average for 3 to 4 weeks before pupating. They move down the food plant into the soil in search of a suitable place for pupation, digging 2 to 3 inches (depending on the compactness of the soil) and burrowing inside to pass the inactive pupal stage. The emergence from the pupae usually takes place after dusk. The adults, after the emergence, rest for a considerable period.

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The fullgrown larva is 3-4 inches long and of light black colour, with its anterior and posterior parts narrower than the rest of the body.

The larva sheds the skin five times. During last two or three days of its life, it attains the maximum length and a light black colour. It feeds on an average of 3 to 4 weeks and then goes into pupation. When full grown, it moves down its food plant and searches for a suitable place for pupation. It then digs about 2 to 3 inches (depending on the compactness of the soil) into the soil and burrows inside for pupation. The size starts getting reduced, the body decolourising, and the feeding is stopped. The second day the size becomes considerably reduced to about 1½ inches with tubular body almost green in colour. During the shortening of the body each segment shrinks. The pupal stage lasts about 3 weeks. The wings may be seen developing from the second day of the pupal stage and the tapering of the abdomen posteriorly may also be observed.

The emergence of adults from the pupae usually takes place after dusk. Out of 8 moths, 5 emerged after dusk, 1 during daylight and 1 early in the morning. The adults after, the emergence, rest for a considerable period and get their wings completely dried before folding them.

III—ACKNOWLEDGEMENT

The author wishes to thank the Director, Zoological Survey of India for identifying the insect.

IV—SUMMARY

The present note is based on observations on a few larvae found in a garden *Impatiens balsamina* and *Zinnia veriicillata*.

The larvae feed voraciously, clinging to the undersurface of the foliage. They prefer tender leaves or only succulent parts of leaves which have somewhat dried up. The biting reflex is initiated soon after the closing of labial palpi on the edge of a leaf and the mandibles start opening and closing to cut the leaf. The defoliation proceeds upward as the larvae move from one leaf to the other immediately above it.

BIOLOGY OF *THERETRA ALECTO* LINN. (LEPIDOPTERA : SPHINGIDAE), A MAJOR PEST OF GRAPEVINES IN RAJASTHAN*

By

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Abstract

Theretra alecto Linn. is a major pest of grapevines in Rajasthan. All the developmental stages are described. A single life-cycle takes 33-42 days from June to September. There are two generations in a year. The pupae of the second generation undergo hibernation in September and give rise to adults in following June.

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NEMATODES IN RELATION TO PLANT DISEASES IN RAJASTHAN

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I—Introduction

Phytonematology has developed at a rapid pace during the past 30 years. Earlier work concerned the endoparasitic nematodes like *Meloidogyne* spp. (root-knot nematodes), *Pratylenchus* spp. (lesion nematodes) and *Heterodera* spp. (cyst nematodes). During those days, if the nematodes were not found inside the diseased material, the disease was usually considered not to be caused by nematodes. With the discovery of new and better techniques, several ectoparasitic forms such as *Belonolaimus* spp. (sting nemotodes), *Xiphinema* spp. (dagger nematodes) and *Trichodorus* spp. (stubby root nematodes) have been shown to be quite destructive. In India, after Butler's (1919) pioneering contribution on 'Ufra' disease of rice caused by *Ditylenchus angustus*, very little has been added to the knowledge of phytonematology from the plant pathological veiw point.

II—Review of Work

Nematodes occur in most habitats, but everywhere they are dependent on water. Since all plant parasitic nematodes have a soil phase, the salient features affecting them are soil temperature, structure, moisture and aeration. Attempts to correlate nematode distribution and abundance with soil type usually do not succeed because of many factors involved. Soil population of plant-feeding and saprophytic nematodes is conditioned by the plants grown. Population of *Heterodera* spp. behave in a fairly predictable way, but not of *Ditylenchus depsaci*, probably the latter being closely related to soil type than to hosts. In our country, practically very little work has been done on the ecological aspects of nematodes, at the most we hear of various species that

A similar circumstantial evidence was forwarded by Nusbaum and Chaplin (1952) about the association of root-knot nematodes with *Phytophthora parasitica* var. *nicotianae*. They observed that soil fumigation with nematicides greatly reduced the magnitude of black shank diseases in the field, as compared to unfumigated controls. They also proved that the fumigants did not have any deleterious effect on the fungus even at high concentrations. Associations of *Rhizoctonia solani* with *Pratylenchus minyus* was confirmed by Mountain and Benedict (1956).

It is interesting to note that *Phytophthora parasitica* var. *nicotianae* does not require wounds to enter into tobacco roots (Nusbaum, 1952). It is, therefore, evident that the breakdown of normal disease resistance is due to something more than mere mechanical injury. An association of this sort still requires investigations to furnish a suitable explanation. Taylor and Wyllie (1959) concluded that the presence of *M. javanica* and *M. hapla* greatly influenced emergenee of soybeans when *Rhizoctonia solani* was also present. Association of *Pratylenchus* spp. with roots of sugarcane plants diseased by the *Sclerospora* fungus was confirmed by Birchfield (1953).

Bacterium-nematode complexes too, have been reported. Evidence has been presented that root-knot nematodes are associated with *Pseudomonas caryophylli* in lowering the resistance of carnations (*Dianthus caryophyllus*) to wilt. Stewart and Schindler (1956) proved it with five species of root-knot nematodes, viz., *Meloidogyne hapla, M. javanica, M. incognita acrita, M. arenaria* and *M. incognita*, separately, as a part of wilt complex.

A similar instance of nematode-bacterium complex has been reported by Lucas, Sasser and Kelman (1955) for Granville wilt of tobacco.

Aphelenchoides ritzomobosi, the cause of 'cauliflower' disease of strawberry, is chiefly an ectoparasite that lives in the folded buds. Pitcher (1951) has reported that this nematode is associated with *Corynebacterium fasciens*, with a combination of bacteria and nematodes both, typical cauliflower tissue was formed. Sting nematodes (*Belonolaimus* spp.) are migratory ectoparasites. Holdeman and Graham (1952, 1953) demonstrated that wilt resistant cotton variety, Coker 100 WR, succumbed to wilt only in the presence of *B. gracilis*. *Helicotylenchus*, when associated with *Pseudomonas caryophylli*, has been reported to bring

are reported from different localities. Chattopadhayay and Sen Gupta (1955) have described *Meloidogyne incognita* on jute *(Corchorus olitorius)*, Different species of *Meloidogyne (incognita, incognita acrita, hapla, javanica, arenaria)* have been reported on potato, tomato, brinjal, 'bhindi', chillies, bean, cucumber, *lagenaria*, radish, and *Luffa* sp. by Thirumalachar (1951), Pushkarnath and Roychowdhury (1958), Lall and Das (1959), and Lall and Ansari (1960). Nematodes on sugarcane have been described by Chona and Gopal Swarup (1960) and Kishen Singh (1960, 1967). The records of occurrence of nematode diseases in India are increasing fast. It is gratifying that Rajasthan is also being explored for the presence of plant parasitic and other nematodes. Yadav and Naik (1966), from the Agricultural Experiment Station, University of Udaipur, reported the presence of plant parasitic and free living nematodes in the root zone of vegetable, horticulture and other economic crop plants in the south-east plateau of Rajasthan. They indicated heavy population of *Meloidogyne, Pratylenchus, Helicotylenchus, Hoplolaimus* and *Tylenchorhynchus*. A comprehensive host-list of *Xiphinema basiri* and *X. indicum* in Rajasthan has also been given by Yadav and Varma (1967).

The association of nematodes in fungal-nematode or bacterial-nematode complexes is a very important aspect in certain soil-borne diseases. Some important associations of plant pathogenic micro-organisms with various genera of nematode are presented here.

The association of *Meloidogyne* sp. with *Fusarium oxysporum* f. *vasinfectum* was first noted by Atkinson in Alabama in 1892. Later, Smith (1953) noted far greater damage to cotton due to wilt-nematode complex than any other disease except Texas root rot. Research for combined resistance to *Meloidogyne* as well as *Fusarium* was thus initiated in cotton breeding programme.

A similar association of *Fusarium oxysporum* f. *lycopersici*, the tomato wilt fungus, with root rot nematode was reported by Young (1939). Harrison and Young (1941) observed that in many varieties of tomato, taken just after rot-knot susceptible crops like cow pea and water melon, damage due to wilt was very heavy. The role of nematodes as cooperators or synergists with *Fusarium oxysporum* f. *nicotianae*, tobacco, wilt fungus, also has been indicated in a report from Georgia (Anon, 1949), where the wilt incidence was reduced after soil fumigation with nematicides.

Ear cockle of wheat, root-knots and 'molya' are some of the important nematode diseases that have been studied in some detail in India (Chidamparanathan and Rangaswami, 1965; Gopal Swarup and Kishen Singh, 1961). 'Molya' disease of wheat and barley was first found by Vasudeva (1957). Prasad *et al.* (1959) reported the nematode to be *Heterodera major (H. avenae)*. Swarup and Singh (1961) proved the pathogenicity of this nematode on wheat and barley.

Efforts to control the nematodes have been made in India. Khan *et al.* (1967) have reported marked inhibition of larval emergence of *Meloidogyne incognita* by the oil emulsion-water extracts from the various oil cakes. For nematodes parasitic on sugarcane, DD and Vapam have been recommended by Kishen Singh (1967). Gopal Swarup *et al.* (1967) found nemafos to be very effective against root-knot nematodes and the ear-cockle disease. At our Research Station at Udaipur, Yadav and Naik (1967) have tried the efficacy of certain nematocides for the control of citrus nematodes (*Tylenchulus semipenetrans*) and found DD, Hexanema and Vapam to be very effective.

Although some progress in phytonematology has been made in India during the last ten years, many fields of this branch are still untouched. We have no account of variation in nematodes. Similarly, the mechanism of nematode injury is another fascinating aspect that has received no attention. Comprehensive surveys and a study of aspects of pathogenic complexes are very necessary. We must also look for control measures which could be practised by our farmers in India. For root-knots, use of resistant varieties, incorporation of chillies or Tagetes along with other vegetables may be profitable. Addition of green leaves of *Azarirachta indica*, *Melia azarirachta*, *Camia fistula*, etc. (200 mds per acre) and saw dust (26 mds per acre) to soil infested with *Meloidogyne javanica* has been reported to reduce the incidence of root-knot in Okra and tomatoes in pot experiments (Singh and Sitaramaiah, 1967). Such experiments should be extended to field investigations in many localities.

An effective control of 'Molya' disease of wheat and barley needs to be worked out. Judging by the work done on phytonematology in India, it can be remarked that more attention is needed on pathological aspects of nematodes and Rajasthan, where it is just beginning, demands immediate attention.

about increase in the incidence of carnation wilt as compared to that caused by bacteria alone (Stewart and Schindler, 1956).

A relationship of *Dilophospora alopecuri*, causal organism of Dilophospora disease of wheat, with *Anguina tritici*, the wheat cockle nematode, was shown by Atanasoff (1925). The same nematode has been reported to be involved in the yellow ear rot of wheat ('Tundu' disease) by Vasudeva and Hingorani (1952). They showed that the characteristic symptoms of the disease were obtained only when *Corynebacterium tritici* and *Anguina tritici* were simultaneously inoculated into the plant.

Pratylenchus pratensis cause such a severe destruction of cotton rootlets that very often they decay off leaving a large number of openings for the entry of wilt fungus (Smith, 1953).

In India, Srinivasan (1958) and Rangaswamy *et al.* (1960) have reported the occurrence of *Meloidogyne javanica* and *Tylenchorhynchus* sp. on sugarcane in association with a *Pythium* root-rot and chlorosis complex.

In many cases, however, the association of nematodes and fungi *is* that of host and parasite, which has a bearing on certain plant diseases. Certain nematodes are known to subsist on fungi and those that parasitize mushrooms are of considerable economic importance (*Ditylenchus* spp.).

Fungi may also be parasitic on nematodes. According to Duddington (1956), there are more than 48 fungi that are known to be capable of trapping, killing and consuming nematodes. The nematodes either get stuck on the adhesive discs of fungi or get entangled in the loops and are subsequently digested. Linford and his associates (1938, 1939) showed that due to predacious action of *Dactyella ellipsospora* the incidence of root knot disease of pineapples is lowered considerably. Unequivocal results about the control of *Heterodera rostochiensis* the golden nematode of potato, through fungi, have been reported from England by Duddington (1956). In India, Sachchidanand and Gopal Swarup (1966) have reported the presence of certain nematophagus fungi (*Cystopage lateralis, Dactylaria psychrophila*, etc.) from Delhi soils.

After the discovery of dagger nematode (*Xiphinema index*) as vector of grapevine fan leaf virus (Hewitt, Raski and Goheen, 1958) many viruses have been reported to be transmitted by nematodes (Rasberry yellow dwarf, tobacco rattle virus, etc.).

III—SUMMARY

Little work has been done on nematodes in Rajasthan, though the soils of State are very favourable for the survival of nematodes which play an important role in causing plant diseases. Surveys carried out by the Nematology Section of the Agricultural Experimental Station, Udaipur, have revealed the presence of many important nematodes like *Meloidogyne* spp., *Helicotylenchus* sp., *Hoplolaimus* sp., *Tylenchorhynchus* sp., *Rotylenchulus* sp., *Pratylenchus* sp., *Xiphinema* sp., *Longidorus* sp., *Paratynchus* sp., etc. Of these, *Meloidogyne* spp. are well known in inciting root-knots and have received some attention in India. Many others have the important role of aiding various soil-borne fungal pathogens, and some of the well recognized complexes are : *Fusarium-Meloidogyne*; *Rhyzoctonia-Pratylenchus*; *Phytophthora-Meloidogyne*; *Rhyzoctonia-Meloidogyne*; *Sclerospora-Pratylenchus*, etc.

Even in many bacterial and viral plant diseases that are soil-borne, nematodes are receiving considerable attention. In India, *Anguina tritici* aids the Tundu-bacterium. In Rajasthan, molya, a nematode disease of wheat and barley, has been studied in some detail by Gopal Swarup and K. Singh (1961).

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PLANT PARASITIC NEMATODES OF RAJASTHAN

By

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(With 1 Table)

I—Introduction

Plant parasitic nematodes constitute a very important and significant part of the soil fauna. Inspite of the importance of agro-nematology, vast areas of the country are still unexplored and lacunae exist in the knowledge of various types of nematodes present in soil, their role and behaviour, frequency, distribution, etc. This is particularly true of Rajasthan where, inspite of a well known nematode problem on wheat and barley ('molya' disease), no intensive survey has been done to explore the nematode fauna of soil. With vast stretches of sandy areas, the soil conditions are ideal for the build-up of nematode populations which might become potential agricultural problems in the near future. However, during the last few years some sporadic surveys were carried out and the results of these surveys, by no means an exhaustive one, are reported herein and the possible problems of the future are indicated.

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Discussion

Dr K.S. Kushwaha Have we started research work on pathology of nematodes as many fungal and other organism have been reported to control these.

Dr N. Prasad : We hope to take up these studies as the efforts are made by the younger trained pathologists, but practically little has been achieved so far in this field

Mr. S.K. Sharma : Do the fungicides play a role in control of root rot of cotton because Brassicole has been used in Shri Ganganagar District and controlled this disease.

Dr N. Prasad : Brassicole is not a nematicide. Root rot of cotton is caused by a fungus so Brassicol can control it as the root rot is secondary infestation of the nematode damage but it is not a cent percent control of the disease.

Mr H K. Vyas : There are numerous fungi which reduce the population of nematodes, and in the event of inoculation of such fungi probably they may also stabilize on the plants, there-by becoming parasitic.

Dr. N. Prasad . There are many fungi which feed upon the fauna of the soil. We must understand the soil which can support such fungi on the nematodes.

Dr. S Khera : Are there phytophagous fungi which may feed on plants as well as on nematodes ?

Dr. N. Prasad : There are no record of nematodes which are both animal as well as plant parasitic

Dr G.C Bhatnagar : In case of wilts of various economic plants, the role of nematodes as causative agents for causing injury to give access to pathogens should be taken into account

Dr. N. Prasad : The role of nematodes in such cases deserves special attention.

was not isolated from the soil, yet the nematode galls generally get in the soil at planting time through the use of contaminated seeds and the larvae emerging from the galls cause infection of the growing wheat seedlings. This is as serious a problem as the 'molya' disease.

The results of the survey presented and discussed above clearly indicate the importance of plant parasitic nematodes in the agricultural economy of Rajasthan. More exhaustive and intensive survey than hitherto reported would no doubt reveal much more the role of the plant parasitic nematodes in some of the unexplained causes of plant malady.

III—SUMMARY

During a survey of cultivated and uncultivated fields of Rajasthan, 21 genera of plant parasitic nematodes representing 41 species were encountered around the rhizosphere of various crops and trees. On the basis of these analysis of soil samples, *Tylenchorhynchus indicus*, *Helicotylenchus retusus* and *Pratylenchus thornei* appear to be potential agricultural problems. Besides these, the root-knot nematodes (*Meloidogyne* spp.), the cereal root eelworm, *Heterodera avenae* (the cause of 'molya' disease in wheat), the ear-cockle nematode (*Anguina tritici*) and the citrus nematode (*Tylenchulus semipenetrans*), already well known and established in Rajasthan soils, are responsible for serious losses to vegetable crops and wheat, barley and citrus respectively.

vulgaris, Pisum sativum, Prosopsis spicigera, Trifolium alexandrianum, Trigonella foenum-graecum, Linum usitatissimum, Lawsonia inermis, Gossypium herbaceum, Morus alba, Musa paradisiaca, Psidium guajava, Phoenix sylvestrix, Punica granatum, Zizyphus jujuba, Citrus aurantifolia, C. sinensis, Capsicum annuum, Nicotiana tabacum, Solanum melongena, Cuminum cyminum, Daucus carota and *Clerodendron splendens.*

The distribution of the genera and species of plant parasitic nematodes in the State as a whole is given in Table 1.

The distribution frequency of the different genera in the soil samples, based on the percentage of soil samples in which they were encountered, were as follows :

Tylenchorhynchus (74.3%); *Helicotylenchus* (55.1%); *Hoplolaimus* (48.7%); *Pratylenchus* (35.9%); *Rotylenchulus* (25.6%); *Meloidogyne* (14.1%); *Telotylenchus* (11.5%); *Heterodera* (10.2%); *Xiphinema* (10.2%); *Trichodorus* (10.2%); *Pratylenchus* (8.9%); *Hemicriconemoides* (8.9%); *Neotylenchus* (8.9%); *Paralongidorus* (6.4%); *Diphtherophora* (5.1%); *Ditylenchus* (4.0%); *Tylenchulus* (2.5%); *Aphelenchoides* (2.5%); *Tylenchus* (2.5%); *Criconemoides* (1.3%) and *Hemicycliophora* (1.2%).

The results show that species of *Tylenchorhynchus* and *Helicotylenchus* are the most prevalent plant parasitic nematodes in Rajasthan soil. Amongst the species of *Tylenchorhynchus, T. indicus* appeared to be an important parasite for a large variety of crops, and particularly gram and cumin at Jaipur were found to support heavy populations of this species. Similarly, *H. multicinctus* appeared to be the most important parasite of banana. *Pratylenchus thornei* at Bikaner was observed to be an important plant parasite of wheat. The soil sample from this area showed more than 70 per cent population of this species and wheat roots were found to be heavily infested with the different developmental stages of the nematode. The crop growth, in general, was very stunted and uneven throughout the field.

Besides the above mentioned potential problems, the root-knot nematodes (*Meloidogyne* spp.) and the cereal root eelworm (*Heterodera avenae*) are already known and well established in Rajasthan soils. The former is a serious limiting factor in vegetable growing in fields and kitchen gardens, and the latter is responsible for the well known 'molya' disease of wheat and barley.

Last but not the least, the ear-cockle nematode (*Anguina tritici*) is a serious menace to wheat cultivation. Though in the present studies it

Table 1 — Concluded

Nematode	% of total samples	Population Density Rating					Total sites	Remarks
		1	2	3	4	5		
Criconemoides sp. ...	5.1	4	—	—	—	—	4	
Hemicriconemoides mangiferae Siddiqi, 1961 ...	5.1	3	1	—	—	—	4	
Hemicycliophora sp. ...	1.2	1	—	—	—	—	1	
Paratylenchus curvitatus Linde, 1938 ...	6.4	4	—	—	1	—	5	
P. nainianus Edward & Misra, 1963 ...	1.2	—	—	—	1	—	1	Aidoo (Amer)
Neotylenchus sp. ...	8.9	7	—	—	—	—	7	
Aphelenchoides bicaudatus (Imamura, 1931) Filipjev & Stek., 1941 ...	1.2	1	—	—	—	—	1	
A. longiurus Das, 1960 ...	1.2	1	—	—	—	—	1	
Xiphinema basiri Siddiqi, 1959 ..	3.9	1	—	2	—	—	3	
X. insigne Loos, 1949 ...	3.9	1	—	2	—	—	3	
Paralongidorus citri (Siddiqi, 1959) Siddiqi, Hooper & Khan, 1963 ...	1.2	1	—	—	—	—	1	
Diphtherophora sp. ...	5.1	3	—	1	—	—	4	
Trichodorus mirzai Siddiqi, 1962 ...	5.1	2	1	1	—	—	4	

Table 1.—Record of plant parasitic nematodes in Rajasthan soils

1 = Rare (below 1%); 2 = Infrequent (1 - 2%); 3 = Frequent (2 - 10%); 4 = Abundant (10 - 50%); 5 = Very abundant (above 50%)

Nematode	% of total samples	Population Density Rating					Total sites	Remarks
		1	2	3	4	5		
Ditylenchus sp.	4.0	3	—	—	—	—	3	
Telotylenchus indicus Siddiqi, 1960	11.5	6	1	—	2	—	9	Barley (Bikaner) *Zizyphus jujuba* (Jaipur)
Tylenchorhynchus acutus Allen, 1955	2.5	1	1	—	—	1	3	Mango, Castor (Jaipur)
T. brevidens Allen, 1955	13.0	1	1	3	5	—	10	Wheat (Ajmer)
T. elegans Siddiqi, 1961	6.4	—	1	3	1	—	5	Gram, *Eruca sativa* (Bharatpur)
T. indicus Siddiqi, 1961	39.7	6	4	16	4	1	31	Gram, Cumin (Ajmer)
T. mashhoodi Siddiqi & Basir, 1959	10.0	1	—	1	5	1	8	Pea Wheat, Mustard (Bharatpur)
T. phaseoli Sethi & Swarup, 1968	5.0	—	2	2	—	—	4	
T. zeae Sethi & Swarup, 1968	2.5	—	—	—	2	—	2	*Cleodendron splendens* (Bikaner)
Tylenchus sp.	2.5	2	—	—	—	—	2	
Helicotylenchus digonicus Perry, 1959	3.5	1	—	1	1	—	3	Sugarcane (Udaipur)
H. dihystera (Cobb, 1893) Sher, 1961	5.1	1	—	3	—	—	4	
H. indicus Siddiqi, 1963	3.2	1	—	1	1	—	3	
H. pseudorobustus (Steiner, 1914) Golden, 1956	11.5	3	3	2	1	—	9	*Citrus sinensis* (Jodhpur)
H. retusus Siddiqi & Brown, 1964	7.7	3	2	—	1	—	6	Banana (Sawaimadhopur)
H. pisi Swarup & Sethi, 1968	2.5	—	—	2	—	—	2	
Hoplolaimus indicus Sher, 1963	34.6	19	3	4	—	1	27	Wheat (Jaipur)
H. pararobustus (Stek & Teun, 1938)	10.2	6	1	1	—	—	8	
Pratylenchus coffeae (Zimmerman, 1898) Goodey, 1951	1.3	—	—	1	—	—	1	
P. loosi Loof, 1960	1.3	—	—	—	1	—	1	Mango (Alwar)
P. penetrans (Cobb, 1917) Chitwood & Oteifa, 1952	5.0	1	—	3	—	—	4	
P. thornei Sher & Allen, 1953	10.2	3	—	3	1	1	8	Wheat (Bikaner)
P. zeae Graham, 1951	15.3	5	3	2	2	—	12	Pennisetum (Udaipur) Wheat (Jaipur)
Rotylenchulus reniformis Linford & Oliveira, 1940	25.6	6	2	4	8	—	20	Papaya, Mulberry (Jodhpur)
Heterodera avenae Wollenweber, 1924	9.0	2	—	2	3	—	7	Wheat, barley (Jaipur)
Meloidogyne arenaria (Neal, 1889) Chitwood, 1949	2.5	—	—	1	—	1	2	Carrot (Jaipur) Brinjal (Sawaimadhopur)
M. javanica (Treub, 1885) Chitwood, 1949	6.4	1	1	1	2	—	5	Mulberry (Jodhpur) Gram (Jaipur)
Tylenchulus semipenetrans Cobb, 1913	2.5	—	—	—	2	—	2	Citrus (Ajmer)

PLANT NEMATOLOGY IN RAJASTHAN : A REVIEW

By

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(With 1 Table)

I—INTRODUCTION

Plant nematology has developed at a rapid pace during the past twenty years. Plant diseases caused by nematodes have been known for a long time, but not until recently have we had a real appreciation of their importance as limiting factors in crop production. This long delay in recognizing nematodes as causative organisms of plant diseases has resulted in an acute and very general need for immediate answers to production problems in agriculture. Besides the well recognised diseases due to certain nematodes which cause tremendous losses to agricultural and horticultural crops, losses in yield may also occur without apparent symptoms of nematode attack. It is possible that undetected losses may be equally important or more so. Such incipient nematode infestations, by remaining unnoticed, may continue for years and, thus, prove to be more harmful economically in the long run. Therefore, it is impossible to assess the economic importance of nematodes in its true sense.

In United States annual losses caused to some of the economically important crops due to nematodes range from 250 to 500 million dollars. Comparable losses must occur in other parts of the globe. It is only during the last two decades that some real attention has been paid in India to this group of organisms. The extent and severity of nematode diseases, as we understand them to-day, leave little doubt that they are an important factor in agricultural production in India and we may be confronted with many nematode problems in future.

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varieties of barley and 25 varieties of oats have been screened for nematode resistance. Of these, six varieties of oats and three of barley showed complete resistance. Singh and Swarup (1964), while making an analysis of the soil samples from 'Molya' infested fields, have observed that a direct correlation exists between population of *H. avenae* in the soil and intensity of the disease and that the nematode completes one life cycle in one crop season under field conditions, This nematode is under investigations in the State Plant Pathology Laboratory.

'Yellow ear rot' of wheat, popularly known as 'Tundu', a disease of nematode-bacterium complex, is spreading year after year in Rajasthan due to the movement of uncertified seeds from infested areas. Singh (1966) from Rajasthan has described the symptoms, etiology, perpetuation etc. of the disease. Twisting of leaves and stems, distortions of earheads and rotting of spike-lets, with profuse oozing of yellow liquid from affected tissues are the chief symptoms of the disease. It is known to be caused by the association of a bacterium, *Corynebacterium tritici* (Hutchinson) with the nematode *Anguina tritici* (Steinbuch). Singh (1966) has opined that the galls might be acting as a carrier of bacterium as healthy seeds in sterilised soil, when sown along with the galls, produced the disease. His experiments have shown that in absence of the bacterium, nematodes cause 'Ear Cockle' disease of wheat. He has further remarked that under Rajasthan conditions the crops were generally less attacked where the sowings were done in optimum conditions of the soil for seed germination and deviations from those conditions made the crop more vulnerable to the attack of the disease. The disease is found to be prevalent in Sriganganagar, Chittorgarh, Bhilwara, Kota and Sirohi districts of the State.

The prevalence of *Meloidogyne* spp. in solanaceous, cucurbitaceous and cruciferous crops, causing galls on their roots, is a great menace to vegetable cultivation in Rajasthan. Infected plants are stunted and show irregular growth. Symptoms of root-knot infestations are commonly observed in brinjal (*Solanum melongena*), tomato (*Lycopersicum esculentum*), okra (*Abelmoschus esculentus*), smooth-gourd (*Luffa cylindrica*), ridge gourd (*L. acutangula*), cowpea (*Vigna sinensis*), carrot (*Daucus carota*), methi (*Trigonella foenum-graecum*), coriander (*Coriandrum sativum*), wheat (*Triticum* sp.), barley (*Hordeum vulgare*), papaya (*Carica papaya*), pomegranate (*Punnica granatum*), mulberry (*Morus alba*), grapes (*Vitis vinifera*), and

Rajasthan is a large State (338,413 sq. kms.) with a wide range of crops and a number of well recognised problems relating to plant nematodes are in the notice. Because of light sandy soils and varied temperature and moisture conditions, we may be confronted with more nematode problems in future. In the State there are three main institutions where problems relating to this science are being tackled, viz. : (1) State Agriculture Plant Pathology Section. (2) Nematology Section of the Experimental Station, University of Udaipur. (3) Department of Zoology, and especially its P.L. 480 Project on Nematology of Millets, at the University of Jodhpur.

II—REVIEW OF RESULTS

The first significant report regarding the prevalence of a serious disease 'Molya' in wheat and barley was made by Prasad *et al.* in 1959 from Rajasthan. *Heterodera avenae* Wollenweber (syn. *H. major*) was found to be the cause of the disease which is characterised by severe stunting of plants, poorly developed root system, poor tillering and inhibited spike emergence. The roots show excessive short rootlets which give a bunchy appearance. The disease was found to be more severe in the light soil regions such as Jaipur, Sikar, Alwar and Ajmer districts. In heavily infested fields, the seedlings are destroyed just after emergence resulting in irregular patchy stand of the crop.

Mathur (personal communication) reports that the disease takes a toll of about 50% yield and in severly infected fields the losses are almost 100%. In the Plant Pathology State Laboratory it has been observed that the life-cycle of the nematode takes 9 to 10 weeks depending upon soil temperature. The optimum temperature for hatching of the cysts is 22°C, though maximum hatching took place when the temperature fluctuated between 18 to 23°C. The percentage hatch of cysts, if stored for longer periods under dry conditions, declines. The field observations indicate that barley crop is more susceptible than wheat, although the multiplication of the nematode on the latter host is faster. The population in fallow fields falls down up to 50% in one year. If such fields are sown with carrot (*Daucus carota*) or 'methi' (*Trigonella foenumgraecum*) as rotation crops, the population still diminishes and if in succeeding years wheat/barley crops are sown, the infection is not severe. Basal application of oil cakes (til, sarson and groundnut) at the rate of 1% results in the reduction of nematode population. 200 varieties of wheat, 100

obtained *in vitro* and a ready stock of these nematodes is now available for undertaking various studies. Tikyani and Khera (1968) have also made studies on the feeding habits of *Telotylenchus paaloofi*. Various pot experiments and other studies in relation to pathogenic behaviour of predominant nematode species are in progress.

Yadav and Varma (1967) have reported the presence of *Xiphinema basiri* from Rajasthan on fifteen new host plants and that of *X. indicum* on *Achras sapota, Eriobotrya japonica, Ficus carica, Mangifera indica, Prunus persica* and *Anona* sp.

Yadav and Naik (1966) studied the effectiveness of various concentrations of certain nematicides for killing of *Tylenchulus semipenetrans* larvae and observed that 'Hexanema' and 'Vapam' killed 90-95% of the larvae within 24 hours. Similar studies were made to evaluate the relative efficacy of Nemafos, Hexanema and Nemagon on some vegetable plants infected with *Meloidogyne incognita* in pots. Nemafos proved to be very effective in increasing yield and killing of nematodes.

The Nematology Section of the Agriculture Experimental Station, Udaipur, is currently working on the following projects : (1) Studies on the plant parasitic nematodes commonly associated with important crops of Rajasthan. (2) Survey of plant parasitic and free living nematodes inhabiting Udaipur soil. (3) Studies on 'Molya' disease of wheat and barley caused by *Heterodera avenae* with special reference to biology, perpetuation control in Rajasthan. (4) Geographical distribution of *Meloidogyne* spp. in Rajasthan.

Swarup and Sethi (1968) have enumerated some plant parasitic nematodes encountered by them as a result of survey of some of the crops in Rajasthan. They have observed that *Tylenchorhynchus* and *Helicotylenchus* were the most predominant nematodes in Rajasthan soil. *Tylenchorhynchus indicus* was found to be associated with a large variety of crops; particularly cumin and gram had heavy populations. *Helicotylenchus retusus* and *Pratylenchus thornei* have been reported to be important parasites of banana and wheat respectively.

Table 1 summarises the knowledge of plant parasitic nematodes recorded so far on different hosts in Rajasthan from various localities.

certain ornamental plants in the State. Although nothing is available in the form of published literature on this serious problem, it is a well recognised fact that the root-knot nematode is causing heavy losses to a large variety of hosts. The problem as such deserves special and immediate attention. Its ultimate solution, however, may lie in the growing of the resistant varieties.

Citrus decline is a serious problem in citrus orchards of Jhalawar, Kota and Jodhpur. The disease appears to be a complex of virus/bacterium/nematode and the problem needs a thorough investigation. The association of *Tylenchulus semipenetrans* is also reported with this disease complex.

A 'P.L. 480 Project' entitled 'Nematode parasites of the great millet and pearl millet and evaluation of varieties for nematode resistance' is in progress in the Zoology Department of the Jodhpur University with the following programme of work : (1) Survey of the main millet growing areas to obtain the root and soil samples of the two millets. Analysis of the samples for plant parasitic nematodes, fungi and bacteria and their culturing. (2) Study of the host-parasite relationship of the predominating nematodes with and without the association of fungi and bacteria and to investigate the disease complex, if any.

As a result of survey of millet-growing tracts of Rajasthan, a large number of nematode genera were encountered from the rhizosphere of great millet and pearl millet. Tikyani and Khera (1968) observed that from around the roots of great millet, *Telotylenchus paaloofi* Tikyani and Khera, *Aphelenchus avenae* Bastian and *Ditylenchus myceliophagus* Goodey were widely distributed; *Hoplolaimus indicus* Sher and *Pratylenchus zeae* Graham were present in about 25% of the samples examined. From the survey of pearl millet fields *Telotylenchus paaloofi*, *T. indicus* Siddiqi and *Tylenchorhynchus indicus* Siddiqi were found to be widely distributed (Nandkumar and Khera, 1970). A new genus and new species, *Neopaurodontus asymmetricus* and five new species, viz. *Telotylenchus paaloofi*, *Nothotylenchus bhatnagari*, *Pratylenchus mulchandi*, *Helicotylenchus goodi* and *Paurodontus aberrans* have been described. A number of nematode species have been cultured on callus tissues and cultures of various fungi. Huge populations of *Telotylenchus indicus* (Khera *et al.*, 1967), *Ditylenchus myceliophagus* (Khera *et al.*, 1968) a number of Aphelenchs (Tikyani and Khera, 1969) have been

Table 1—Continued

Host	Nematodes and Localities	Remarks
	18,20,21,22,23,26,29), *A. radicicolus* (14,17,20,22,29), *Paraphelenchus myceliphthorus* (16,17,26), *Aphelenchoides subtenuis* (14,16,17,19,20 22), *Ap. asterocaudatus* (14,17)	
Maize (*Zea mays*)	*Criconemoides, Helicotylenchus, Hoplolaimus, Tylenchus, Tylenchorhynchus* (All from 27)	
Cotton (*Gossypium* spp.)	*Criconemoides, Helicotylenchus, Hoplolaimus, Pratylenchus* (All from 27)	
Ground nut (*Arachis hypogea*)	*Helicotylenchus, Pratylenchus, Tylenchus* (All from 27)	
Sugarcane (*Saccharum officinarum*)	*Helicotylenchus, Hoplolaimus, Tylenchus, Tylenchorhynchus* (All from 27)	
Cowpea (*Vigna sinensis*)	*Meloidogyne* spp. (31)	
Sannhemp (*Crotolaria juncea*)	*Helicotylenchus, Hoplolaimus, Pratylenchus* (All from 27)	
Coriander (*Coriandrum sativum*)	*Helicotylenchus* (27), *Hoplolaimus* (27), *Tylenchus* (27), *Meloidogyne* (13)	
Turmeric (*Curcuma domestica*)	*Helicotylenchus, Hoplolaimus, Tylenchus* (All from 27)	
Chillies (*Capsicum annum*)	*Helicotylenchus, Hopolaimus, Tylenchus, Meloidogyne* (All from 27)	
'Methi' (*Trigonella foenum-graecum*)	*Meloidogyne* sp. (31)	
Brinjal(*Solanum melongena*)	*Helicotylenchus* (27), *Hoplolaimus* (27), *Pratylenchus* (27), *Tylenchus* (27), *Meloidogyne* (31)	
Okra (*Abelmoschus esculentus*)	*Helicotylenchus* (27), *Hoplolaimus* (27), *Tylenchus* (27), *Tylenchorhynchus* (27), *Meloidogyne* spp. (31)	
Tomato (*Lycopersicum esculentum*)	*Meloidogyne* (31)	
Carrot (*Daucus carota*)	*Meloidogyne* (13)	
Lablab bean (*Dolichos lablab*)	*Meloidogyne* (14)	
Cabbage (*Brassica* var. *capitata*)	*Helicotylenchus, Hoplolaimus, Pratylenchus, Tylenchus* (All from 27)	
Cauliflower (*Brassica oleracea* var. *botritis*)	*Helicotylenchus, Hoplolaimus, Meloidogyne, Pratylenchus* (All from 27)	
Bittergourd (*Monordica charantia*)	*Meloidogyne* (27), *Neotylenchus* (27)	
Smoothgourd (*Luffa cylindrica*)	*Meloidogyne* (31)	
Ridge gourd (*L. acutangula*)	*Meloidogyne* (31)	
Banana (*Musa paradisica*)	*Tylenchorhynchus* spp. (13,14,30), *Meloidogyne* (30), *Hoplolaimus indicus* (14,30), *Helicotylenchus dihystera* (14), *H. indicus* (14,30), *H. sp* (13), *H. microcephalus* (30), *H multicinctus* (30), *Nothotylenchus* sp. (13), *Boleodorus* sp. (13), *Paurodontus* sp. (13), *Xiphinema basiri*	*Helicotylenchus dihystera* was the most predominating nematode
Mango (*Mangifera indica*)	*Tylenchorhynchus* spp. (30), *Hoplolaimus indicus* (30), *Helicotylechus indicus* (14,30), *H. udaipur-*	*Helicotylenchus indicus* and

Table 1.—Plant parasitic nematodes recorded on different hosts from Rajasthan

Localities : 1. Abu Road, 2 Ajmer, 3 Alwar, 4. Anatpura, 5. Banar, 6. Bassi, 7. Bhilwara, 8. Bilara, 9. Bundi, 10 Chittorgarh, 11. Durgapura, 12. Gobindgarh, 13. Jaipur, 13-2. Jhalawar, 14. Jodhpur, 15 Kota, 16. Lamba, 17. Mandor, 18 Mehlan, 19. Merta city, 20. Nagaur, 21 Nasirabad, 22. Pali, 23. Reodar, 24. Sardarsamand, 25. Sikar, 26 Sirohi, 27 S E. plateau of Rajasthan, 28. Sriganganagar, 29 Sumerpur, 30. Udaipur, 31. Distributed all over the State.

Host	Nematodes and Localities	Remarks
Wheat (*Triticum sativum*)	*Heterodera avenae* (2,3,12,13,25), *Anguina tritici* (7,10,26,29), *Meloidogyne* spp.	*H. avenae* cause 'Molya' and *A tritici* 'Ear cockle' diseases
Barley (*Hordeum vulgare*)	*Heterodera avenae* (2,3,13), *Meloidogyne* sp.	
Paddy (*Oryza sativa*)	*Helicotylenchus* (27), *Radopholus* (27)	
Sorghum (*Sorghum vulgare*)	*Tylenchorhynchus* sp. (14,16,19,20,22), *Ditylenchus myceliophagus* (1,2,5,9,14,16,19, 20,21,22,29), *Ditylenchus* sp. (9,14,15,16,19), *Pseudhalenchus anchilisposomus* (2,14,16,19, 20,21), *Telotylenchus indicus* (5,14,17), *T paaloofi* (2,5,9,14,15,16,17,18,20,21,22,29), *Hoplolaimus indicus* (2,14,16,17,21), *Scutellonema* sp (14 16), *Helicotylenchus* sp. (2,9,21, 23), *Pratylenchus zeae* (2,9,14,15,16,17,19,20, 21,22), *Nothotylenchus bhatnagari* (14), *Neopaurodontus asymmetricus* (14,16), *Criconemoides* sp (2,21), *Aphelenchus avenae* (1,2, 5, 8, 9, 14, 15, 16, 17, 19, 20, 21, 22, 26, 29), *A. radicicolus* (14,17,20,29), *Paraphelenchus myceliophthorus* (1,26), *Aphelenchoides subtenuis* (14,23,26), *Ap. asterocaudatus* (19)	*A. avenae*, *T. paaloofi* *D. myceliophagus*, *P. zeae* were wide-spread
Bajra (*Pennisetum typhoides*)	*Hoplolaimus indicus* (11,14,16,17), *Scutellonema* sp (14,16), *Helicotylenchus indicus* (16,18,19), *Helicotylenchus* sp. (6,22), *Heterodera avenae* (11,21,22), *Pratylenchus zeae* (5,14,17), *P. mulchandi* (16,19), *Tylenchorhynchus indicus* (1,9,14,15,16,17,20,21,22, 25), *Tylenchorhynchus* sp. (2,6,9,14,15,16, 17,29), *Ditylenchus myceliophagus* (1,2,8,14, 15,16,17,19,20,22 23,26,29), *Ditylenchus* sp. (6,14,16,21), *Telotylenchus indicus* (2,8,9, 14,15,16,17,22,26), *T. paaloofi* (1,2,5,6,8,9, 14,15,16,17,18,19,20,22,23,26,29), *Pseudhalenchus anchilisposomus* (4, 11, 14, 16), *Paurodontus* sp. (14), *Nothotylenchus* sp. (4,5,6,8,9,12,14,15,16,17,20,21,22,23,26, 29), *Basiliophora* sp. (6,11,14,17), *Paratylenchus* sp (16), *Aphelenchus avanae* (1, 2, 4, 5, 6, 8, 9, 11, 12, 14, 15, 16, 17,	*A. avenae*. *T. paaloofi* and *D. myceliophagus* were widespread

Table 1—Concluded

Host	Nematodes and Localities	Remarks
Falsa (*Grewia asiatica*)	*Helicotylenchus, Pratylenchus, Tylenchus, Tylenchorhynchus, Xiphinema* sp. (All from 27), *Xiphinema basiri, X. indicum*	
Fig (*Ficus carica*)	*Helicotylenchus, Hoplolaimus, Criconemoides, Meloidogyne, Pratylenchus* (All from 27), *Xiphinema basiri*	
Pears (*Pyrus communis*)	*Crico-nema, Helicotylenchus, Hoplolaimus, Tylenchus, Xiphinema* sp. (All from 27), *Xiphinema basiri*	
Rose (*Rosa indica*)	*Helicotylenchus, Tylenchorhynchus, Xiphinema* sp. (All from 27), *X. basiri*	
Cactus (*Thoro-puntia* spp.)	*Helicotylenchus, Hoplolaimus, Tylenchorhynchus, Xiphinema* (All from 27)	
Citrus limonia, Eribotrya japonica, Zingeber officinale, Phyllanthus emblica, Prunus persica	*Xiphinema basiri*	All these are new hosts for *Xiphinema basiri*
Achras sapota, E. japonica	*Xiphinema indicum*	

III—SCOPE FOR FUTURE WORK

While contemplating the future of nematology, we must provide a broad programme of research to build up a store of knowledge and programme of instructions to pass this knowledge to students and an organisation of extension workers who should also be familiar with local conditions and problems. They should, in turn, make the cultivators thoroughly aware of the seriousness of nematode pests.

Rajasthan can be broadly divided into four different zones on the bases of different soil types, climatic conditions, the amount of rainfall, etc. Initially a crop-wise survey of plant parasitic nematodes in the different zones is the first desirable step in recognising the problems of nematodes. As far as possible the incidence of different nematodes as well as the percentage population along with the symptoms caused and an assessment of losses, if possible, should be worked out. Koch's postulates, viz. (1) constant association of the suspect organism with the disease; (2) isolation of the suspect organism in pure culture; (3) reproduction of the disease by inoculation with the pure culture of the organism; and (4) re-isolation of the organism from the inoculated diseased host

Table 1—Continued

Host	Nematodes and Localities	Remarks
	ensis n sp. (30), *Hemicriconemoides* sp. (28), *Boleodorus* sp. (14,30), *Paralongidorus* sp. (28), *Xiphinema basiri*	*Paralongidorus* sp. were wide spread
Papaya (*Carica papaya*)	*Meloidogyne* spp. (14,23), *Hoplolaimus indicus* (13), *Arolaimus israeli* (28), *Helicotylenchus dihystera* (14), *H. microcephalus* (30), *Paratylenchus* sp (14,30)	
Mulberry (*Morus alba*)	*Tylenchorhynchus* spp (13,14,28,30), *Telotylenchus indicus* (14), *Meloidogyne* sp (14), *Hoplolaimus indicus* (30), *Hoplolaimus* sp (14), *Helicotylenchus* sp. (30), *H indicus* (30), *Paratylenchus* sp (14), *Nothotylenchus* sp (14), *Boleodorus* sp (30), *Paralongidorus* sp (14,28), *Xiphinema indicum* (14)	
Guava (*Psidium guajava*)	*Telotylenchus indicus* (14), *Hoplolaimus indicus* (30), *Hoplolaimus* sp. (13,14), *Helicotylenchus* spp. (28 30), *H. dihystera* (13), *H indicus* (30), *Pratylenchus brachyurus* (14), *Paratylenchus* sp. (14), *Paranothotylenchus bifurcatum* n g., n sp. (30), *Boleodoroides* sp. (30), *Xiphinema basiri*	
Pomegranate (*Punica granatum*)	*Tylenchorhynchus* spp. (14,30), *Telotylenchus indicus* (14), *Heterodera* sp (30), *Hoplolaimus indicus* (13,14), *Helicotylenchus* sp (30), *H indicus* (30), *H. microcephalus* (30), *Criconemoides* sp. (28), *Paralongidorus* spp. (14), *Xiphinema indicum* (14), *X. basiri*	
Grapes (*Vitis vinifera*)	*Tylenchorhynchus* spp. (13,14,27), *Telotylenchus indicus* (14), *Heterodera* sp. (14,28), *Hoplolaimus* sp (13,14), *H. indicus* (2,14,30), *Helicotylenchus* sp. (30), *H. indicus* (2,14), *H. crenacauda* (18), *Paratylenchus* sp. (14), *Nothotylenchus* sp. (14), *Boleodorus* spp (30), *Boleodoroides* sp. (30), *Pauradontus* sp. (14), *Xiphinema indicum* (14), *X basiri* (14), *Longidorus sylphus* (14)	
Lime (*Citrus aurantifolia*)	*Tylenchorhynchus* spp (30), *Telotylenchus indicus* (14), *Hoplolaimus indicus* (30), *Helicotylenchus* sp (30), *H. indicus* (14), *Paratylenchus* sp. (14), *Xiphinema indicum* (14), *Tylenchulus semipenetrans* (13-2,15,17)	
Malta (*Citrus sinensis*)	*Tylenchorhynchus* spp. (18,30), *Telotylenchus indicus* (14), *Meloidogyne* sp. (28), *Hoplolaimus indicus* (13), *Helicotylenchus indicus* (14,15), *H microcephalus* (30), *Helicotylenchus* sp. (30), *Hemicycliophora* sp. (14), *Hemicriconemoides* sp. (14), *Paratylenchus* sp., *Paranothotylenchus bifurcatum* n g, n sp. (30), *Paralongidorus* sp. (14), *Xiphinema basiri* (14), *Criconemoides* (27), *Tylenchulus* (27)	
Orange (*Citrus reticulata*)	*Tylenchorhynchus* spp. (13,30), *Hoplolaimus indicus* (13), *Helicotylenchus* spp. (30), *H. indicus* (14,30), *H. microcephalus* (30), *Tylenchulus semipenetrans* (13-2,15,17) *Xiphinema basiri*	

the association of the nematode *Anguina tritici* and the bacterium *Corynebacterium tritici* is found in severe form in Sriganganagar, Chittorgarh, Bhilwara, Kota and Sirohi districts of the State. The disease is characterised by the twisting of leaves and stems, distortion of the earheads and rotting of spike-lets with profuse oozing of yellow liquid from the affected tissues.

Meloidogyne spp. are known to parasitise a wide variety of hosts in Rajasthan. The infected plants get stunted with development of knots on the roots. The nematode deserves immediate and special attention.

The survey of pearl millet and great millet fields has yielded a large number of plant parasitic nematodes from their rhizospheres. A number of new forms have been described. Some nematode species have been cultured *in vitro*.

Nematodes of chief fruit plants and vegetables have been surveyed in the State. *Xiphinema basiri* has been reported on fifteen new hosts from Rajasthan. *Arachis sapota, Ficus carica, Eriobotrya japonica, Mangifera indica, Prunus persica* and *Anona* sp. are reported to be new hosts for *X. indicus*.

It would be most appropriate to include Plant Nematology in curriculum at post-graduate level for students of helminthology or plant pathology.

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and its identification with original inoculant, will have to be applied for proof of pathogenicity under strict laboratory conditions. A programme can then be charted out on priority and urgency bases both in the field and in the laboratory. Biology and life cycle studies of the important nematodes will have to be made so as to locate weak chains in the life of the parasite. Finally an inexpensive practical control method in the form of resistant varieties, chemical nematicides or a cultural or biological control may have to be evolved.

To give due recognition to plant nematology, and especially looking to its increasing significance, it would be most appropriate to introduce the teaching of this subject either by itself or as a part of plant pathology or helminthology curriculum at postgraduate level with special emphasis on field work. The training of plant protection workers should include sufficient knowledge of plant nematology so that they can recognise nematode problems in the field. All this is possible only if there is a general awareness and acceptance of nematode problem at the scientist's, agriculturalist's and government levels.

IV—Acknowledgements

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V—Summary

Because of light sandy soils and varied temperature and moisture conditions in Rajasthan we may expect many more nematode problems. A thorough consciousness of plant nematode disorders is, therefore, essential.

'Molya' of wheat and barley, caused by the nematode *Heterodera avenae* is the most serious plant disease in Rajasthan. Severe stunting of plants, poorly developed bunchy root system, poor tillering and inhibited spike emergence are the characteristic symptoms. Six varieties of oats and three of barley have been reported to be completely resistant to this nematode in Rajasthan.

Yellow ear rot of wheat, popularly known as 'Tundu' caused by

Heterodera sp., *Hirschmanniella* sp., *Hoplolaimus indicus*, *Helicotylenchus* sp., *Longidorus* sp., *Meloidogyne incognita*, *M. javanica*, *Pratylenchus delattrei*, *P. thornei*, *P. zeae*, *Rotylenchulus reniformis*, *Tylenchorhynchus bilineatus*, *T. mashhoodi*, *T. brevidens*, *T. martini*, *Tylenchulus semipenetrans*, *Trichodorus ? aequalis*, *Xiphinema basiri* and *X. indicum*. He considers *Heterodera* spp. in cereals, root knot and *Rotylenchulus* in vegetables and *Tylenchulus semipenetrans* in citrus as major problems of the State.

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ADDENDUM

The following new species of tylenchid (plant parasitic) nematodes have been described from Rajasthan : *Pratylenchus mulchandi* Nandkumar and Khera, 1969, *Paurodontus abberans* Tikyani and Khera, 1969, *Nothotylenchus bhatnagari* Tikyani and Khera, 1969, *Helicotylenchus goodi* Tikyani, Khera and Bhatnagar, 1969, *Telotylenchus paaloofi* Tikyani and Khera, 1970, *Aphelenchoides jodhpurensis* Tikyani, Khera and Bhatnagar, 1970. The first species was recovered from the rhizosphere of gramand pearl millet whereas the other five species were recovered for the first time from the rhizosphere of great millet.

Large populations of *Tylenchorhynchus phaseoli* were found to be associated with guar and cowpea particularly in sandy and sandy loam areas of Rajasthan (Sethi and Swarup, 1969).

An intensive survey of the pearl millet growing districts of Rajasthan yielded the following results : *Telotylenchus paaloofi* was found in 85%, *Tylenchorhynchus indicus* in 52%, *Telotylenchus indicus* in 43% and *Hoplolaimus indicus*, *Helicotylenchus indicus* and *Pratylenchus mulchandi* in 19% of the 21 localities surveyed. Species of *Scutellonema* and *Paratylenchus* were restricted to one locality. In all about 25 tylenchid nematode species were recorded (Nandakumar and Khera, 1970).

Root knot nematodes (*Meloidogyne javanica* and/or *M. incognita*) occur on the roots of cowpea, green gram, guar, watermelon, muskmelon, pea and brinjal. Work on resistant varieties is being carried out (Mathur, Dalela, Mathur and Handa, unpublished).

Yadav (unpublished) has recorded the following nematodes from Rajasthan which are of agricultural importance : *Anguina tritici*, *Criconemoides georgii*, *Hemicycliophora transvaalensis*, *Heterodera avenae*, *H. zeae*,

SOME INVESTIGATIONS ON THE 'MOLYA' DISEASE OF WHEAT AND BARLEY IN RAJASTHAN

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(With 7 Tables)

I—Introduction

Prasad *et al.* (1959) first reported the cereal-cyst nematode *Heterodera avenae* Wollenweber 1924, as a pest of wheat and barley crops in Rajasthan. Further observations revealed the eelworm to be well established in Sikar, Jaipur and Alwar districts of the State. It is responsible for a serious disease of wheat and barley crops locally known as 'Molya' disease. The yield losses to the crops due to this eelworm are estimated to exceed fifty percent and in severely infested fields total crop failures have also been observed. Over widespread areas in these districts the cereal-cyst nematode has obviously been attacking these cereal crops for many years without cultivators being aware of the true cause of their poor or indifferent crops. Often the unthriftiness of a crop was ascribed to the season, poor soil, insufficient manures or fertilizers or some other factor. However, pathogenicity tests conducted by Swarup and Singh (1961) and subsequently by the author indicate that the disease is directly traceable to attacks by the cereal-cyst nematode.

The diseased plants are pale looking and do not grow more than 1-2 ft. in height. In newly infested areas the disease occurs in patches, however, with repeated cultivation of these cereal crops the disease infects the whole field. The infection starts in November when second stage larvae emerge out of the cysts and infect young seedlings of wheat and barley. The disease seedlings become pale yellowish-green in

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another at Govindgarh were selected to study the decline of the population of the cereal-cyst nematode under fallows and non-host crops. Soil sampling was done in both the fields in October before the commencement of the trial and the results indicated a uniform infestation in both the fields. Soil samples were washed for the determination of eggs and larvae as described by Goodey (1963). Carrot (*Daucus carota* L.), fenugreek (*Trigonella foenum-graecum* L.) and gram (*Cicer arietinum* L.) are generally grown by the cultivators of the area, and hence these crops were included in the investigations. The layout of the experiment was randomised block design and six replications of each treatment, viz. fallow, carrot, fenugreek and gram, were taken. The population of the eelworm in the soil at the end of the season was determined and the results are presented in Table 1.

For varietal resistance screening trial, soil samples from six randomly choosen infested sites in Rajasthan were collected in the month of October in 1967, and stored out of doors in large cement pots. In November each soil was thoroughly mixed and the number of eggs and larvae per 100g of soil sample were determined according to Goodey (1963). Table 2 shows the origin and level of cereal-cyst nematode infestation.

Andersen in Denmark used for many years and found the porous clay pipes the best for testing the resistance to the cereal-cyst nematode. Similar porous, non-glazed clay pots of 30 cm length and 5 cm internal diameter were used during this trial. These pots were filled with infested soil, 120 varieties of wheat belonging to *Triticum durum*, *T. aestivum*, *T. diococcum*, *T. turgidum* and *T. sphaerococcum* species, 112 varieties of barley belonging to *Hordeum vulgare* and *H. distichon* species, and 15 varieties of oats were tested for resistance. In addition *Avena sterilis*, petkus spring rye, Timothe, English rye grass and Italian rye grass were also included. The tests were replicated three times. Three seeds were sown in each pot of which only one seedling was kept per pot. Pots were watered as necessary and during the growing season the plants were dressed with a granular mixed fertilizer. All the replications were examined for the development of cysts on the roots after about 14 weeks of planting. The above ground parts of the plants were cut off and the clay pots were soaked in a tray of water and the number of cysts on the roots were counted.

colour with poor root formation. A number of small rootlets develop giving the roots a bunchy appearence. The diseased plants do not tiller well. The roots of 2-3 month old plants show white female bodies of the nematode adhering to them. The female bodies later on turn brown and remain in the soil to infect the host crops in the following years. In the diseased plants no or very few grains are formed. Barley crop has been observed to be more adversely affected by the pest than wheat crop.

Bhatnagar *et al.* (1965) working in Rajasthan tested the resistance of one hundered varieties of barley (both *Hordeum vulgare* and *H. distichon*) in infested fields at Durgapura Farm and showed that the two-rowed varieties, Prior A.Q. 1127, A.Q. 253, Research A.Q. 853 (belonging to *H. distichon*) were resistant to the attack of cereal-cyst nematode. These workers indicated that with this resistant material a breeding programme for the evolution of nematode resistant barley could be initiated. However, the author found that in many infested fields of the State the cereal-cyst nematode was able to multiply strongly on these varieties. This might suggest the existence of variability in the pest and occurrence of biotypes.

Variation in pathogenicity of the cereal-cyst nematode has been clearly demonstrated by European workers (Andersen, 1959; Cotton, 1962; Kort *et al.*, 1964; Fiddian and Kimber, 1965). It is necessary to study the variability of this parasite before initiating breeding programme. To ascertain whether any such variation occurs in our State, the varieties have to be tested against cereal-cyst nematode populations from different sites throughout the infested districts of the State. A start has been made in this direction in the present investigations.

During 1966-68 inclusive, experiments have been conducted by the author into the effect of fallowing, growing non-hosts on the population of the eelworm and screening of the existing varieties of oats, wheat and barley for resistance against this disease. The field trials in connection with these investigations were conducted on cultivator's fields in Jaipur district heavily infested with *H. avenae*. The laboratory and greenhouse studies were performed at the plant pathological laboratory, Durgapura, Jaipur.

II—Material and Methods

During *rabi* 1966-67 one cultivator's field in Rampura-Dabri and

2. *Varietal screening in oats, barley, wheat and other grasses*

Table 2.—Origin of six soils and level of cereal-cyst eelworm population

Soil No.	Origin	No. of eggs and larvae per 100 g. of soil.
1.	Anatpura	1380
2.	Bairath	1050
3.	Govindgarh	1910
4.	Neem-ka-Thana	980
5.	Rampura-Dabri	1630
6.	Srimadhopur	1650

Table 3.—Number of new cysts of H. avenae *formed on three plant roots of oat varieties and* Avena sterilis

Variety	Anatpura 1	Bairath 2	Govind garh 3	Neem-ka-Thana 4	Rampura Dabri 5	Srimadhopur 6
C.I. 2095	0	0	0	0	0	0
C.I. 2154	0	0	0	0	0	0
C.I. 3445	0	0	0	0	0	0
C.I. 3449	0	0	0	0	0	0
C.I. 5188	0	0	0	0	0	0
P.I. 175021	0	0	0	0	0	0
C.I. 2863	0	0	0	0	0	0
P.I. 185775	2	0	0	0	0	0
C.I. 5194	0	10	0	3	0	33
P.I. 194897	0	0	0	2	0	0
P.I. 175024	0	1	0	0	0	0
P.I. 181004	70	0	0	0	0	0
P.I. 175022	0	0	0	0	6	0
Sun II	0	0	1	0	0	0
P.I. 181003	0	0	6	0	0	0
Avena sterilis	10	1	3	0	36	45

(a) *Oats*

During *rabi* 1967-68, fifteen oat varieties and *Avena sterilis* were tested for resistance. All these varieties except Sun II oats were found to be resistant against all biotypes of the Netherland by Kort *et al.* (1964).

The results indicate that C.I. 2095 (Australian origin), C.I. 2154, C.I. 3445, C.I. 3449, C.I. 5188, P.I. 175021 (all of Indian origin) and C.I. 2863 (Argentinian origin) showed resistance to all the six populations. Occasional cysts were observed on the roots of P.I. 185775,

III—RESULTS

1. *Effect of fallows and non-host crops*

At Rampura-Dabri, the percentage decline in population under fallows, carrot, fenugreek and gram was 49.66, 54.50, 54 and 53% respectively. In the trial conducted at Govindgarh the percent fall in population of cereal-cyst nematode under fallows, carrot, fenugreek and gram was 50.66, 55.50, 54.00 and 52.50 respectively. However, in both the trials no significant difference was observed between the different treatments.

Table 1.—Decline in the infestation of soils in one year under fallows and non-host crops

Location of experiment	Rampura-Dabri	Govindgarh
Treatment	% decline over initial population (a)	% decline over initial population (b)
Fallows	49 66	50.66
Carrot	54 56	55.50
Fenugreek	54.00	54 00
Gram	53 00	52.50
Standard Error (mean)	1.56	1.56
C V.	7%	7%

(The initial population at Rampura-Dabri and Govindgarh was 2310 and 3580 eggs and larvae (per 200 g of soil) respectively (*a*) and (*b*) are average decline percentages of 6 replications.)

N.B.—The decline of population in different treatments in both the trials is not statistically significant.

The results indicate that if a field infected with cereal-cyst nematode is kept fallow or sown with non-host crops (carrot, gram and fenugreek), the level of eelworm infestation may fall down by about 50 percent in one year, and that the population decrease may even be upto 55 percent. The data of the decline of the population in the different treatments of the trials do not show significant differences among them. From the results, it may be inferred that although growing non-host crop reduces the level of the eelworm in diseased fields, it does not have any extra influence in the decline of population of cereal root eelworm as compared to fallowing.

Table 4.—Number of new cysts of H. avenae *on three plant roots of barley varieties*

Variety	Anatpura 1	Bairath 2	Govind-garh 3	Neem-ka-Thana 4	Rampura-Dabri 5	Sri-madhopur 6
Morocco C.I. 3902	0	0	0	0	0	0
Marocaine 079 C.I. 8334	0	0	0	0	0	0
Statsfrkontrollens Alfa	0	0	0	0	0	0
Kron	0	0	0	0	0	0
P.I. 253826	0	0	0	0	0	0
C.I. 3515	36	27	21	12	30	3
Pajbjerg Drost	0	0	1	2	2	7
Fero	3	0	0	0	4	0
Rex	6	0	0	0	0	0
Hanna export	2	0	0	0	54	0
Goldfoil C.I. 928	2	0	0	3	0	0
Ogalitsee C.I. 7152	14	0	0	0	0	x
I.B D.N. 61 No. 14	2	0	0	3	0	0
Barley 191	2	1	0	0	6	21
Ariana C.I. 2524	36	75	1	18	3	5
Herta	94	63	98	153	3	118
Kenia	203	186	116	189	5	200
Maja	224	113	81	250	0	75
Opal	254	201	110	140	6	210
Quinn C.I. 1024	125	36	15	151	25	37
Harlaan 43	3	0	0	197	27	2
A Q. 230	101	36	11	27	153	1
A.Q. 378	x	15	21	165	150	0
A.Q. 679	7	0	0	93	150	0
A.Q. 768	12	6	0	0	2	14
A.Q 769	x	6	0	16	27	0
A Q. 800	7	0	0	39	0	17
A Q. 1127	270	40	18	0	24	76
B. 19	90	30	4	301	41	0
B. 52	170	54	15	36	63	0
B. 61	0	0	0	302	54	1
B. 667	172	30	3	9	92	0
B. 668	0	0	0	2	0	0
B. 675	0	3	0	67	0	3
B G. 1	225	30	2	125	62	82
B R. 22	1	0	2	54	27	36
N P. 1	21	15	12	180	65	3
N P. 103	122	50	54	301	48	0
N P. 104	1	0	0	0	0	25
Prior	125	43	9	63	118	0
Research	24	3	1	64	134	0

x : Pots were broken.

P.I. 175024 (Indian origin), P.I. 194897 (Ethiopian origin) and Sun II varieties of oats. P.I. 181004 carried a large number of cysts in Anatpura soil and bore none in other soils. C.I. 5194 bore systs in Bairath, Neem-ka-thana and Srimadhopur soils but did not carry cysts in soils from other sites. P.I. 175022 and P.I. 181003 produced cysts in Rampura-Dabri and Govindgarh soils respectively, but did not produce cysts in other soils. *Avena sterilis* bore no cysts in Neem-ka-thana soil and only a few cysts in Bairath and Govindgarh soils where as it produced a large number of cysts in Rampura-Dabri and Srimadhopur populations.

(b) Barley

During the tests 112 varieties, both Indian and exotic, were tested for resistance. These included barley varieties used by Kort *et al.* (1964) in the Netherlands and by Bhatnagar *et al.* (1965) in India. Sixty nine varieties carried a large number of cysts in all the six populations and were termed as highly susceptible (their results are not given here). Forty-three barley varities show differences in susceptibility towards the different populations of the cereal-cyst nematode.

The results indicate that 5 barley varieties, viz. Morocco C.I. 3902, Marocaine 079 C.I. 8334, Statsfrkontrollens Alfa, Kron and P.I. 253826 showed resistance against all the six populations of the nematode. Occasional cysts were produced on the roots of Fere, Rex, Goldfoil C.I. 928, I.B.D.N. 61 No. 14 and B. 668 varieties of barley in the different soils. Although N.P. 104 barley carried moderately large number of cysts in Srimadhopur population, it bore only one cyst in Anatpura soil and none in other soils. Ogalitsee C.I. 7152 barley produced only in Anatpura soil. Herta, Kenia, Maja and Opal varieties of barley carried a large number of cysts in Anatpura, Bairath, Neem-ka-thana and Srimadhopur soils but produced relatively fewer or no cysts in Govindgarh and Rampura-Dabri population. Prior barley did not produce cysts in Srimadhopur soil where as A.Q. 1127 did not produce cysts in Neem-ka-thana populations. Research barley did not bear cysts in Srimadhopur soil and only one cyst in Govindgarh soil.

(c) Wheat

Of the 120 varieties, both Indian and exotic tested for resistance, none proved to be resistant to all the six populations of the nematode.

Table 6.—Number of cysts of H. avenae *on three plant roots of Petkus spring rye, Timothe, English rye grass and Italian rye grass*

Name	Anatpura 1	Bairath 2	Govind-garh 3	Neem-ka-Thana 4	Rampura-Dabri 5	Srimadhopur 6
Petkus	x	22	61	9	5	6
Timothe	15	3	3	15	0	5
English rye grass	x	0	3	5	8	3
Italian rye grass	x	6	x	x	5	0

x denotes broken pots.

rye grass did not carry cysts in Bairath and Srimadhopur soils respectively.

IV—DISCUSSION

1. Effect of fallowing and sowing non-host crops

Hesling (1958) estimated the population decline of cereal cyst nematode, under fallows or non-host crop to be about 60% in one year. Duggan (1958) working in field and microplots observed the decline in the population of the nematode. In his trial 52, 53, 50, 48 and 60% decline in population was observed under lucerne (microplot), Lucerne (field plot), fallows, rye grass-cocksfoot-clover mixture and roots respectively. Similar decrease in the level of infestation was observed under lucerne and root crops (potatoes and beets) by Andersen (1961). The results reported herein are in line with these workers and under Rajasthan conditions a minimum decline of about 50% in cereal-cyst population in one year in different treatments was observed. Although the decrease in population was observed to be slightly more in non-host crop than in fallows, in both the trials the decline percentage do not show significant differences over fallowing. It is presumed that the reasons of decline in population under these non-hosts are the same as under fallow.

Second stage larvae of *H. avenae* under suitable environmental conditions emerge from the cyst and move about in the soil in the search of host roots. In the absence of hosts these larvae starve and die and thus account for a major decrease of population of this nematode in the soil. The emergence of larvae in the cereal-cyst

106 wheat varieties produced large number of cysts in all the six population and were termed as highly susceptible (their results are not given here). However, the 6 varieties and 8 lines of wheat showed differences to the different populations of the nematode.

Table 5.—Number of cysts of H. avenae *on three plant roots of wheat varieties*

Variety	Anatpura 1	Bairath 2	Govindgarh 3	Neem-ka-Thana 4	Rampura-Dabri 5	Srimadhopur 6
C A 50	125	20	0	25	53	9
C C 308 3	370	70	0	39	42	29
H D 25-61-1961	336	109	0	93	90	17
S 331	89	12	0	45	9	9
H D 38-1621	334	100	21	297	9	0
Dwarf durum	39	54	33	21	0	6
H.D 62-125	250	120	13	27	80	0
Loros 5 63	24	5	0	22	2	54
Loros 9,63-5	16	0	0	21	2	5
Loros 6 63	18	1	0	36	0	10
Loros 2/63	12	0	0	11	0	5
Loros 7 63	50	0	0	51	2	7
Loros 9 63-3	20	0	0	3	0	5

The results indicate that all the varieties carried a large number of cysts on their roots in Anatpura soil, and all except one line (Loros 9/63-3) in Neem-ka-thana soil. The lines of Loros did not produce cyst in Govindgarh soil, and either none or only occasional cysts in Bairath and Rampura-Dabri soils. In Srimadhopur population the Loros lines produced from a few to quite large number of cysts. H.D. 38-1621 and 62-125 wheat varieties also did not carry cysts on their roots in Srimadhopur population. Dwarf durum variety did not produce any cyst on its roots in Rampura-Dabri population. C.A. 50, C.C. 308-3, H.D. 25-61-1961 and S.331 did not produce cyst in Govindgarh population.

(d) Other grasses

Petkus spring rye, Timothe, English rye grass and Italian rye grass were tested for resistance.

Petkus spring rye, produced cysts in all the five observed populations. The roots of Timothe did not produce cysts in Rampura-Dabri soil. From the results available it is clear that English rye grass and Italian

reported earlier by Bhatnagar *et al.* (1965) were found to be resistant against only one or two populations of the state.

In wheat the situation so far is not very optimistic, and of all the tested varieties none was resistant against all the six populations of the nematode. The Loros lines found to be resistant by Holm-Nielsen (1966) in Denmark were found to be attacked by 2-3 local populations of the cereal-cyst nematode.

The results provide enough evidence of the existence of variability of the cereal-cyst nematode, in this State. The author tried the differentials used by Andersen in Denmark and Kort *et al.* in the Netherlands, with the intention to base the results as much as possible on the results of these workers. However, the data indicate that the physiological specialisation in Rajasthan is much too different either from Denmark or the Netherlands. Using the cereal differentials used by European workers the situation in Rajasthan is summarised in Table 7.

Table 7.—Reactions of cereal indicator varieties to known European biotypes and to 6 different populations of H. avenae *in Rajasthan*

R = Resistant, S = Susceptible, — = not tested

Indicator variety	DENMARK		NETHERLANDS				RAJASTHAN					
	I	II	A	B	C	D	Anatpura	Bairath	Govindgarh	Neem-ka-thana	Rampura-Dabri	Srimadhopur
Sun II Oats	S	S	S	R	S	R	R	R	R	R	R	R
Pajbjerg Drost barley	R	S	R	R	S	R	R	R	R	R	R	R
191 barley	R	R	R	S	R	R	R	R	R	R	R	S
Herta/Maja Opal Kenia barley	S	S	S	R	S	S	S	S	S	S	R	S
I.B.D.N. 61 No 14 barley	—	—	R	R	S	S	R	R	R	R	R	R
Morocco C.I. 3902 barley	R	R	R	R	R	R	R	R	R	R	R	R
RS 17	—	—	—	—	—	—	S	S	S	S	S	S
RS 31-1 wheat	—	—	—	—	—	—	S	S	S	S	S	S

As would appear from the above data populations from Anatpura, Bairath, Govindgarh and Neem-ka-thana are identical. These populations closely resemble the biotype D of Kort *et al.* as these populations do not produce cysts on Sun II oats, Pajbjerg Drost and 191 barley

nematode has not been shown to be influenced by root exudates of host and non-host crops (Hesling, 1957). The results reported herein provide an evidence to the view and indicate that exudate from non-host crop like carrot, fenugreek and gram do not influence the emergence of larvae from cysts in the field. It may, therefore, be inferred that the decline in population in non-host crops is to be regarded simply as the effect of fallowing.

However, in the districts of Rajasthan, where 'Molya' disease occurs, wells are the only means of irrigating the crops. Obviously, well irrigation when employed in a conservative way, i.e. by using a pair of bullooks to pull out a 'charas' full of water, has its own limitations with regard to the area covered under irrigation. As such one year crop rotation with carrot on fenugreek, or gram is recommended for economic reasons. It was observed that the cultivator could take a moderate crop after one year rotation with these non-host crops.

2. *Varietal resistance studies*

Andersen (1961) defined a resistant plant in which a nematode is not able to form cyst or a plant on which only a small number of cysts are produced. The same definition is adhered to in these investigations. According to this definition a resistant plant does not necessarily escape damage, but very often resistant plants are some what less damaged than the susceptible ones.

Among oats eleven varieties, viz. C.I. 2095, C.I. 2154, C.I. 3445, C.I. 3449, C.I. 5188, P.I. 175021, C.I. 2863, P.I. 185775, P.I. 175024, P.I. 149897, and Sun II were found to be resistant to all the six populations. All these varieties except sun II oats were found to be resistant against all the biotypes found in the Netherlands by Kort *et al.* (1964).

In barley five exotic varieties, viz. Morocco C.I. 3902, Marocaine 079 C.I. 8334, Statsfrkontrollens Alfa, Kron and P.I. 253826 showed complete resistance in the six populations of Rajasthan. The first two varieties were shown by Kort *et al.* (1964) to be resistant to all the biotypes of the Netherlands, and the remaining three varieties against A, B and D biotypes. The other promising varieties which showed occasional cysts are Fero, Rex, Goldfoil C.I. 928, I.B.D.N. 61 No. 14 and B. 668 of barley. Prior, Research and A.Q. 1127 varieties of barley

VI—SUMMARY

'Molya' disease of wheat and barley caused by *Heterodera avenae* Woll., is responsible for enormous yield losses in Sikar, Jaipur and Alwar districts of Rajasthan. Severe stunting of plants, poorly developed root system, poor tillering and spike emergence are the symptoms of its attack.

Decline in the level of eelworm population under non-host crops (carrot, fenugreek and gram) and fallows for one year under field condition was studied and the results indicate that if an infected field is fallowed or sown with these non-host crops the level of infestation will fall by at least fifty percent in one year. Population decrease under fallows and non-host crops did not differ significantly and it is inferred that the decline in population under non-host crops is to be regarded simply as the effect of fallowing.

Experiments for varietal resistance using different populations of the cereal-cyst nematode indicated that eleven varieties of oats and five varieties of barley showed resistance to all the populations of *H. avenae* obtained from six different localities. The results also clearly demonstrate the occurrence of physiological differentiation in cereal-cyst nematode in Rajasthan for the first time.

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varieties and produce a high number of cysts on Herta/Maja/Kenia/Opal and RS 17/RS 31-1 varieties. However, these populations differ from the biotypes D found in the Netherlands because the barley variety I.B.D.N. 61 No. 14 mentioned as susceptible to biotype by Kort *et al.* did not carry any cyst in these soils.

Rampura-Dabri population does not produce cysts on Sun II oats, Pajbjerg Drost, 191, Herta/Maja/Opal/Kenia varieties and produces cysts only on RS 17 barley and RS 31-1 wheat. The population present in Srimadhopur soil produces cysts on 191, Herta, RS 17/RS 31-1 and does not produce cysts on Sun II and Drost. A comparison with the reactions of known European biotypes reveal that the populations from Rampura-Dabri and Srimadhopur do not resemble to any biotype of Andersen and Kort *et al.* and appear distinctly different.

From the above discussion it is clear that physiological differentiation of cereal-cyst nematode do exist in Rajasthan State. The conclusions regarding the number of biotypes present in the State are by no means final, and the whole situation regarding the number of races occuring in the province will only become clear when more populations of *H. avenae* from sources throughout the State will be tested. Further work on these lines is in progress. As a result of the present investigations resistant varieties, both in oats and barley, have been found which may serve as a starting point for breeding for resistance against cereal-cyst nematode.

V—Acknowledgements

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NEMATODE PESTS OF CERTAIN VEGETABLES OF JODHPUR

By

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(With 1 Table)

I—Introduction

A lot of work is being carried out in Rajasthan on insect pests but little attention has been given to nematodes affecting vegetables, particularly in the western part of Rajasthan. An attempt has been made here to find out the nematodes parasitizing common vegetable plants. This will facilitate healthy growth of vegetables.

Emphasis is laid here on the main plant parasitic nematodes, but, where possible, notice has been taken of the free-living forms found in association with the plant parasitic nematodes. These include usually the members of the families Acrobelidae and Cephalobidae. The genera *Tobrilus* and *Dorylaimus* were also recovered.

Yadav and Naik (1966), while surveying the association of plant parasitic nematodes with economic plants in south-east plateau of Rajasthan, reported *Helicotylenchus*, *Hoplolaimus*, *Tylenchus* and *Meloidogyne* in chillies; *Meloidogyne* sp. in *methi*; *Hoplolaimus*, *Pratylenchus*, *Tylenchus* and *Meloidogyne* in brinjal; *Meloidogyne* sp. in carrot; and *Helicotylenchus*, *Hoplolaimus*, *Tylenchus*, *Tylenchorhynchus* and *Meloidogyne* spp. in *okra*. These genera, were also recovered by these workers around other hosts, viz., tomato, cabbage, cauliflower, bitterguord, smoothguord, and ridgeguord.

II—Results

The authors found *Meloidogyne* sp. galls on brinjal (*Solanum melongena*), okra (*Abelmoschus esculentus*) and *methi* (*Trigonella faenum-graceum*). The plants associated with this nematode showed stunted and unthrifty growth in the fields. Symptoms of association of other nematodes with their hosts were less marked and hence not diagnostic.

Discussion

Dr. K.S. Kushwaha : While screening the varieties for nematode resistance, have you also studied the factors, internal constitution or external morphological characters responsible for such a resistance.

Dr. B.N Mathur: It is only the genetic character which has to be studied. No morphological characters are so far known to distinguish resistance to *H. avenae* I am intending to work out chromatographic characters.

Dr. S. Khera : Has the resistant gene in wheat variety been associated with any character ?

Dr. B.N. Mathur : No.

Dr. S. Khera : Have you taken account of the yeild also while determining resistant varieties ? It is just possible that there may be a large number of cysts and still the yield may be excellent. After all it is a matter of economics.

Dr. B.N. Mathur : The experiment was done with a limited number of varieties. It was found that plants having 5-7 cysts escaped damage and those having more than 7 cysts had stunted growth.

The infection resulted in stunted and unthrifty growth of the plants in the fields. The symptoms of association of other nematodes with their hosts could not be perceived.

The authors report for the first time the association of a number of nematodes with several vegetables.

V—REFERENCE

Yadav, B.S. and Naik, S.M. 1966. Nematodes associated with economic plants of south-east plateau of Rajasthan. *Labdev (J. Sci. & Tech.)*, Kanpur, 4 : 184-186.

The plant parasitic nematodes recovered in and around the roots of vegetable plants by the present workers are listed in Table 1.

Table 1.—List of the plant parasitic nematodes found associated with vegetable plants in Jodhpur

Host	Nematode
Carrot *(Daucus carota)*	*Aphelenchus avenae*, *Tylenchorhynchus* sp. and *Hoplolaimus indicus*
Chillies *(Capsicum anum)*	*Boleodorus* sp. and *Helicotylenchus* sp.
Brinjal *(Solanum melongena)*	*Aphelenchoides* spp. and *Meloidogyne* sp.
Potato *(Solanum tuberosum)*	*Aphelenchus avenae* and *Ditylenchus* sp
Okra *(Abelmoschus esculentus)*	*Tylenchorhynchns* sp , *Aphelenchus avenae* and *Meloidogyne* sp.
Radish *(Raphanus sativus)*	*Aphelenchoides* spp , *Tylenchorhynchus* sp., *Aphelenchus avenae*
Methi *(Trigonella foenum-graceum)*	*Aphelenchoides* sp., *A. subtenuis*, *A. besseyi*, *Xiphinema* sp. and *Meloidogyne arenaria*
Mustard *(Brassica compestris)*	*Aphelenchoides* sp. and *Aphelenchus avenae*
Spinach *(Spinacia oleracea)*	*Aphelenchoides besseyi*, *A.* sp. and *Boleodorus* sp.
Onion *(Allium cepa)*	*Nothotylenchus* sp. and *Boleodorus* sp.

Observations on *Meloidogyne* sp. galls on *methi*, brinjal and *okra* roots in Jodhpur indicate that probably this nematode infests these plants all over the Rajasthan. The authors report, for the first time, the association of various plant parasitic nematodes with potato (*Solanum tuberosum*), radish (*Raphanus sativus*), mustard (*Brassica compestris*), spinach (*Spinacia oleracea*) and onion (*Allium cepa*) from Jodhpur.

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IV—SUMMARY

The authors found *Meloidogyne* sp. galls on brinjal (*Solanum melongena*), *okra* (*Abelmoschus esculenta*) and *methi* (*Trigonella faenum-graceum*).

STUDIES ON THE EFFECT OF CHEMOSTERILANTS. I. CHEMOSTERILIZATION IN INSECTS WITH SPECIAL REFERENCE TO GRASSHOPPERS AND COCKROACHES*

By

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I—Introduction

To bring about a downward trend in a population of pests, natality can play a more important and effective role than mortality. Our experiences in past with insecticides have compelled us to shift the strategy from mortality to natality. Several chemicals have been screened and found very effective against certain insects. Chemosterilants call for several aspect to be considered, before they are employed for the purpose. The main idea behind the use of an insecticide is to obtain a kill, whereas in case of chemosterilants the toxicity becomes a disqualification. A chemosterilant should only affect the reproduction physiology of the insect so as to make them incapable of reproducing without interfering with other physiological aspects.

II—Results

All over the world attention is focussed on the search and the effects of chemicals capable of sterilising the pests. India has not been able to attract many entomologists in this field. Studies on the effects of apholate and tepa on grasshoppers and cockroaches, carried out in the Toxicology Laboratory of Zoology Department of University of Rajasthan, have revealed very interesting and promising results. We have been able to discover the doses of both the chemosterilants to sterilize these insects.

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UNGULATES IN THE GREAT INDIAN DESERT : A PHYSIOLOGICAL APPRAISAL

By

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(With 3 Tables)

I—Introduction

The desert contains a developed and characteristic biota and multitude of environmental niches. The growth forms of plants range from grasses through shrubs, succulents to small trees, forming communities according to soil types and salinity of the soil water (Purohit, 1967, 1968).

Ecologically the desert appears as a simple habitat but the inhabiting life periodically faces the problems of extremes of temperature, decline in the quantity of food, and scarcity or absence of water for most part of the year. Unquestionably, the seasonal insufficiency of nutritionally adequate food would lead to malnutrition, starvation or death, whereas scarcity of water induces migration or dehydration, and prolonged water deprivation is usually fatal.

Cultivation in Rajasthan is dependent on monsoon irrigation. Therefore, stock farming plays a significant role in the economy of man. More than two-thirds of the area being arid or semi-arid, management of stock brings a multitude of problems. To assess and beneficially utilise the animal resources in the State, fundamental information on the requirements of the animals, particularly herbivorous ruminants that are closely associated with their masters, is needed. Wild ungulates such as antelopes or donkey or other ruminative animals may become nice biological laboratories for studies.

Recently the author (Purohit, 1968) pointed out that much of the studies on the biology of animals living in the Great Indian Desert have been concerned about documentation of the natural history, and a little

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is added on the food and water requirement of mammals. In general, much of the available literature on the physiology of desert mammals is on rodents living in the Northern Hemisphere. There is some physiological information on camel and sheep as desert ungulates (Schmidt Nielsen, 1964; Macfarlane, 1968). While reviewing the information on the biology of mammals in the Great Indian Desert, it occurred to the author that we need to know how our wild and domesticated mammals meet their nutritional requirements, particularly during summer droughts. Here the author outlines the problems of water, salt and nitrogen encountered by the desert ungulates, and discusses possibilities, rather than make a comprehensive statement, on the utilisation of the animal resources.

II—Habitat and Diversity of Ungulates

Hoofed mammals or the ungulates gregariously live in herds. Except for the domesticated cattle, goat, sheep and donkeys, others are nomadic, cursorial beasts, experiencing striking ecological contrasts and extremes of temperature in their vast geographical ranges. The following species are common in the Great Indian Desert : the Indian Antelope, *Antilope cervicapra*; the Nilgai or Blue Bull, *Boselpus tragocamelus*; the camel, *Camelus dromedarius*; the Indian Gazelle, *Gazella gazella*; the sheep, *Ovis arienes*; the goat, *Capra hircus;* cattle; Asiatic wild ass, *Equus hemonus;* and wild boar, *Sus scrofa cristatus* (Table 1).

III—Food as a Source of Energy and Protein

Information on food of ungulates (Table 1) reveals that feral as well as domesticated ungulates are herbivorous and prefer grasses and parts of deep rooted plants such as *Prosopis* and *Zizyphus* species.

Cellulose is one of the largest energy-yielding component of terrestrial green plants. The utilisation of cellulose by animals is, therefore, a subject of great importance. Unfortunately, no vertebrate secretes an enzyme system which will attract the β-confriguration of the 1-4 glucosodic linkages of cellulose and so librate energy. However, during the course of evolution, some herbivorous verteberates have overcome this absence by adopting symbiotic anaerobic bacteria as their cellulase producing tissue. The microorganisms are harboured in digestive tract and nourished by the host, and the host, in turn, receives fermented products

needs, it is now agreed that ruminative animals do not have to be fully dependent on exogenous nitrogen supply. The fermented food when hydrolysed in the true stomach also kills microorganisms and, thus, provide bacterial protein. Furthermore, the nitrogen can be supplied in the form of ammonium salt or urea. Studies on camel (Schmidt-Nielsen *et al.*, 1957), sheep (Houpt, 1959; Hogan, 1961) and ruminant-like macropods (Brown and Main, 1967; Purohit, 1969) have confirmed that when protein depleted or feeding on low protein diet urea produced by the animals is retained. The endogenous urinary urea can then diffuse through the gut-wall or may enter the rumen or fermentive chamber via saliva. In the presence of adequate amount of energy, the urea-N may be transformed into bacterial protein and then utilised by the host.

Unqeustionably, such physiological regulation of the endogenous urea attains considerable significance, particularly during summer droughts, when plants are declined in energy and nitrogen contents. In extreme conditions, this may become a deciding factor for survival of the population. Data on this aspect of the phenomenon are still rare. Kinnear and Main (unpublished) found that at the height of the mid-summer droughts on the East Wallabi Island (Western Australia) the Tammar wallaby (*Macropus eugenii*) are protein depleted, and that at such times they recycle urea nitrogen. Under laboratory conditions, the author observed that the Tammar wallaby also recycle endogenous urinary urea-N and thus supplement their protein needs (Purohit, 1969).

Leaves of *Zizyphus* have high protein content (14.5-14.9 g %) and pods of *Prosopis spicegera* have 68-70% of water. Raheja and Sen (1964) reported that important perennial grasses in Rajasthan are *Lasiurus sindicus*, *Sehima nervesium*, *Dichanthium annulatum*, *Cenchrus ciliaris*, *C. setigerus*, and *Panicum antidotale*. These grasses are nutritious. palatable and productive. These can withstand severe grazing once fully established. No information on nitrogen and water contents is available. Nor do we know about the protein needs of any species. However, it seems likely that protein level in the vegetation will change through the season in which case it might be expected that seasonal changes in diet would occur. The preference of the ungulates for deep rooted plants such as *Prosopis* and *Zizyphus* suggested of high protein diet in which seasonal changes in protein contents are not likely to be extreme.

as a source of energy. These mammals are called ruminants—they are cloven-hoofed mammals that chew their cud, and the process is called rumination. The group includes some of the economically important domestic animals such as cattle, sheep, goat, and among feral beasts are the antelope and the gazelle. Some of the Australian herbivorous macropod marsupials (wallabies and kangaroos) possess characteristics of ruminative digestion, and have been classified as ruminant-like mammals. The stomach of ruminative mammals is complex and usually can be distinguished as the rumen, reticulum, omasum and abomasum (for details see any text on anatomy of domesticated mammals).

With regard to the site of bacterial fermentation, mammals can be grouped into two groups : those presenting their ingested food for fermentation prior to gastric digestion (pre-gastric fermentation) such as true ruminants and ruminant-like mammals, and those in which fermentation occurs in the hind-gut, such as the lagomorphs (Moir *et al.*, 1956; Griffiths and Davis, 1963). Among perissodactyles, the stomach is generally simple but there are some signs of anatomical diversification of the cardiac regions. It is not certain whether their development ever reaches the stature adequate to provide conditions suitable for fermentation to occur (Moir, 1965).

It follows that ruminative animals are at an advantage over the monogastric mammals. The ingested food is acted upon by the microorganisms in the fore-stomach and produces volatile fatty acids (VFA). Since the ruminative mammals lack liver glucokinase this VFA provides major energy requirements. Studies have shown that in the ruminative system, dietary glucose and other carbohydrates are converted to VFA in the gut. Little glucose is absorbed into the portal blood and, consequently, the liver does not have a mechanism for rapid uptake and storage of the glucose (Ballard, 1965). Naturally, the animals become dependent on the continuous production of VFA by rumen microbes. In the absence of this source of energy, the only other source of required energy will be by muscle breakdown (gluconeogenesis) which, if continued, may lead to pathogenic symptoms.

Our information on the nutrition of the ungulates is not sufficient to give a general synthesis. However, from studies on ruminative mammals it is clear that the chances of their going without food for a prolonged period would unquestionably be fatal. As regards protein

(2) increasing water conservation. Ungulates due to their size remain exposed to diurnal heat and in summer months cannot go without water. A linear increase in insensible water loss with an increase in the ambient temperature necessitates a supply of drinking water. The situation becomes more critical in hot summer months when the animal needs more water to maintain homeostasis of the internal environment, while at the same time free surface water, if at all available, evaporates more rapidly against the higher ambient temperatures. The most dependable water source under such circumstances is water from available forage. Drinking of saline water, as discussed earlier, if available in the vicinity of their habitats, may be a solution in some cases.

Table 3.—Tolerance and weight loss for desert mammals on water deprivation

Species	Duration days	Percent from initial weight lost	Source
Camel	9	19-21	Macfarlane (1963)
Donkey	4	30.4	Schmidt-Nielsen (1957)
Sheep : Merino	9	31-32	Macfarlane (1963)
Marwari	4	25	Taneja (1965)
Gazella	5	24	Ghobrial & Cloudsley-Thompson (1956)

Most animals have adjusted to low water intake or have become independent of exogenous water intakes. Sheep of Marwari breed, indigenous to the Indian deserts, have been observed to tolerate a short term water deprivation, and satisfy their water requirements by water from high water content plants such as *Prosopis spicigera* (Taneja, 1965). This suggests a low water requirement as well as low water turn over. Studies have shown that a low water turn over is an efficient mechanism for summer in deserts but is reflected in low production of wool at least in Australian Merionos (Macfarlane, 1964).

In the desert inadequate water supplies during most part of the year induce practical difficulties in the way of controlled grazing or fodder conservation. Either one can maintain a few heads of high producing stock that individually have high water requirements or one can have many heads of low producing stock each with low water requirements. In the latter case the stock may exceed the carrying capacity of the range and over-grazing may result; consequently upon

Table 2.—Urine concentration in some desert mammals

Species	Milliosmol	U/P ratio	Urea m moles/l	Source
Camel	2,760	8	—	Schmidt-Nielsen (1964);
	3,170	—	—	Schmidt-Nielsen *et al.* (1957)
Eland Lab.	2,050	6	—	Taylor & Lyman
Field	2,050	—	810	(1967)
Hereford	1,300	4	—	— do —
Merino sheep	3,190	—	1,500	McDonald & Macfarlane (1958)
Tammar Wallaby	1862-3337	6-9	32-789	Purohit (1969)

The ability of desert mammals to produce concentrated urine (Table 2) and resist water deprivation have enhanced their survival, particularly during the periods of water deficiencies. Macfarlane (1964) pointed out that the interstitial fluid was much involved in the regulation of fluid distribution during dehydration. He showed that reduction in salivary flow (97%) and in duodenal flow rate (94%) were comparable with that estimated for loss of gut water in camel (90%).

IV—DISCUSSION AND CONCLUSIONS

Sheep-rearing is one of the major industries of Rajasthan which produces 30 million pounds of greasy wool, about 45 percent of India's annual output. Besides, Rajasthan has the monopoly in camel, supply of goat for mutton to neighbouring states and drought resistant cattle breeds. The wild ungulates, considered as game and tourist attraction only, could become a good source of animal protein particularly when the country is protein deficit. The export of wool, meat and other animal products such as ghee, hides, dung as manure or fuel is essential to the economy of the human population inhabiting the desert areas in Rajasthan.

Management of stock in deserts encounters two major problems : adequate supply of feed and water. Unfortunately, both of these have been in shortage in desert regions.

The desert-inhabiting animals have two possible solutions to the problems of water shortage : (1) minimise their water requirements, and

It follows that, in a desert region one has to decide either to have a few heads of highly productive stocks that, as discussed earlier, would have high water and food requirement or relatively large herds of low productivity, which undoubtedly will have low requirements.

Pending further information and understanding about the requirements of the ungulates of the Great Indian Desert, it is too early to propose any general statement on their utilisation. However, the following conclusions may safely be drawn :—

Seven species of ungulates (domesticated and feral) occupy characteristic ecological niches in the local desert. Domesticated ungulates are essential to economy of Rajasthan. Seasonal shortage of feed and water restrict the size of stock otherwise management of large herd will be uneconomical. At present it is not known whether the ungulates in this desert can benefit from saline water; how they meet their nitrogen requirements; how efficient are their renal and digestive mechanisms in processing ingested electrolytes with food and drink; and what are the ecological requirements in the local habitat ? Information on the underlying physiological mechanisms is needed and this necessitates extensive field and laboratory studies in accordance with local requirements. Further domestication and ranching of wild ungulates would lead to beneficial methods for preservation, research and alleviating the protein deficient diet of most people in India.

V—ACKNOWLEDGEMENTS

I wish to thank Professor A.R. Main for his suggestions and encouragement during the preparation of the review which was done while holding the tenure of a University of Western Australia Research Studentship (1965-1968). Thanks are also due to my father, Sri Kishan Gopal Purohit, for reading the final draft of the paper and to Sri Shyam Singh for typing the manuscript.

VI—SUMMARY

The Great Indian Desert contains a developed and characteristic biota. The growth forms of plants range from grasses through shrubs, succulents to small trees, forming communities according to soil types and salinity of the soil water. Ecologically the desert appears as a simple habitat but the inhabiting life periodically faces the problems of extremes

over grazing the forage may become dominated by coarse, unpalatable low feed value plants at the expense of the perennial, highly nutritious grasses. Such over grazed situations are not uncommon in the Great Indian Desert.

In the development of modern breeds of domestic animals the emphasis is on rapid growth and high productivity so that a large fraction of the feed consumed is used in the production of meat, milk and wool, and only a small fraction is used for maintenance of the stock. A suitable breed of stock for arid region should, in addition to these qualities, possess abilities to conserve water and have low water requirement. It has been shown that in nature these attributes tend to be mutually exclusive, hence any breeding programme devoted to improving productivity of domestic stock in the desert is, while water supply is short, likely to have to be a compromise, i.e. productivity cannot be taken for an absolute maximum while water intake is to be restricted.

It is now established for ruminative mammals that the urea produced by the animal itself can be recycled and utilised as a nitrogen source. In the presence of an energy (usually available from cellulose) it can be converted to bacterial protein, which can be digested and absorbed lower in the gut. The process of recycling of urea removes urea or non-protein nitrogen (NPN) from the body fluids as effectively as does the renal excretion (Houpt, 1959). Thus the ability of ruminative animals to convert NPN to bacterial protein, particularly on low nitrogen feed, has at least two apparent advantages : (1) conservation of water, which otherwise would have been obligated for excretion of urea; and (2) inbuilt supply of nitrogen for synthesis of bacteria protein.

From a production point of view in desert region, it is a common fact that as the summer progresses the available forage dries out and the nitrogen content declines, resulting in a poor quality of feed so far nitrogen is concerned. On the other hand cellulose material increases. Under such circumstances animals face a shortage or absence of water and nitrogen deficit food. Saline or brackish water is the only supplementary source of drinking in various parts of the Great Indian Desert. Theoretically, if an animal system can benefit from drinking salt water, i.e. by excreting urine with high electrolytes (possible with kidney of high RMT index) and has ruminative system of digestion then the situation is ideal.

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POLYMORPHISM IN BLOOD POTASSIUM IN SHEEP

By

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(With 6 Tables and 4 Text-figures)

I—INTRODUCTION

The conventional method for livestock production is to select animals on the basis of performance of the individual, its progeny or its ancestor. The literature is fully loaded with various selection experiments carried out on these conventional methods. Many problems such as the collection of data over several years, the complexity of statistical analysis, the influence of the personal factor in data collection, etc., are encountered by the geneticists conducting breeding experiments using the conventional methods of selection. Notwithstanding the fact that these methods have helped in creating genetic improvement to some degree, the difficulties met with in them are well recognised and there is, therefore, a need to find some short cut methods which could save time and also increase the accuracy of prediction of the performance of the individual animals.

In recent years several non-conventional methods for direct selection of individuals, based on the presence or absence of certain biochemical constituents and their concentrations in animals have been very widely used. It is supposed that there may be 3 kinds of genetic associations between blood characters and productivity : (1) by linkage; (2) through pleiotrophy; and (3) from interaction between alleles at a locus or between loci. The first two cases would probably lead to straightforward additive superiority or inferiority of certain genetypes over others. The third situation would result in over-dominance so that animals heterozygous for the alleles in question would possess some kind of measurable superiority over homozygous animals. Recently,

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we have taken up a project on the role of sodium and potassium in the blood of sheep with a view to select animals on the basis of concentration of these electrolytes for higher production.

II—OBJECTIVES

There is sufficient evidence in the literature (Evans, 1954; Evans and Mounib, 1957) suggesting that on the basis of concentration of potassium in the blood, sheep can be classified into high or low potassium types. In the highlands of Great Britain, which has a comparatively colder climate, there is a relatively larger number of HK type animals whereas in an arid country like Australia the number of low potassium animals is very high. These ecological distributions formed the basis of our study on the relative merits of these two potassium types in relation to their adaptation to arid areas and their performance under these conditions. With this background we undertook a series of experiments to determine the physiological differences between the two potassium types in various breeds of sheep in Rajasthan in their level of production and adaptation to arid conditions.

III—RESULTS AND DISCUSSIONS

1. Blood Potassium Types in Rajasthan Desert

A survey of five sheep breeds of Rajasthan, viz. Marwari, Malpura, Chokla, Magra and Sardarsamand, has shown that on the basis of concentration of potassium in the blood, the animals in each breed can be classified into two distinct groups—high (HK) and low (LK) potassium types. Text-fig. I indicates the distribution of potassium concentration for two breeds (Marwari and Chokla) for which the data are voluminous. It is apparent that there is no intermediate type between high and low, although the tail ends of the two normal distributions tend to meet each other and the animals lying on the tail ends sometime pose a problem in deciding whether they may be classified as high or low. Such cases are, however, rare.

Results in Table 1 indicate that when sheep are differentiated on the basis of concentration of potassium in the red blood cells, 4 groups emerge. These are called alpha, beta, gamma and delta. LK is termed as alpha and HK is sub-divided into 3 groups—beta with equal concentration of sodium and potassium, gamma with less sodium and

Table 2.—Distribution of HK sheep in various breeds of Rajasthan

Breed	No of sheep	% HK sheep
Chokla	259	57
Malpura	99	65
Magra	115	65
Marwari	113	72
Sardarsamand	12	66

The proportion of HK type varies from 57 to 72 per cent in different breeds (Table 2). In Rajasthan the HK type predominates over LK and this led us to postulate that if the ecological distribution of potassium types on a global basis as reported in the literature is accepted, the only possible likelihood of the high proportion of HK type in Rajasthan desert could be due to migration in the past of sheep flocks from the colder desert areas of Afghanistan to this region. Another possible explanation for the high proportion of HK type in our desert could be that under these conditions, HK has certain advantages which out-weighed those of LK. This suggested to us to study the relative differences between these two types in their adaptation to desert conditions.

2. *Adaptation*

How these two potassium types are adapted to meet the stress of various kinds prevalent in the region is one of the basic questions. The answer to this we thought should explain the differences in these two types for adaptation to desertic conditions. One of the stresses prevalent in this region is that produced by scarcity of water. Therefore, we first measured the normal water intake in these two types. We found, that, on equal body weight basis, the LK type sheep drank relatively lesser quantity of water. On a larger sample, when potassium types were adjusted for variations in body weight, the differences between types for water intake were, however, not statistically significant, but the interaction between season X type was significant. The differences in water intake by the two types of animals, therefore, varied from season to season. An examination of the data in one of the experiments also revealed that actually the differences were largely in mode than in mean. That is, there were more animals in the LK than in the HK

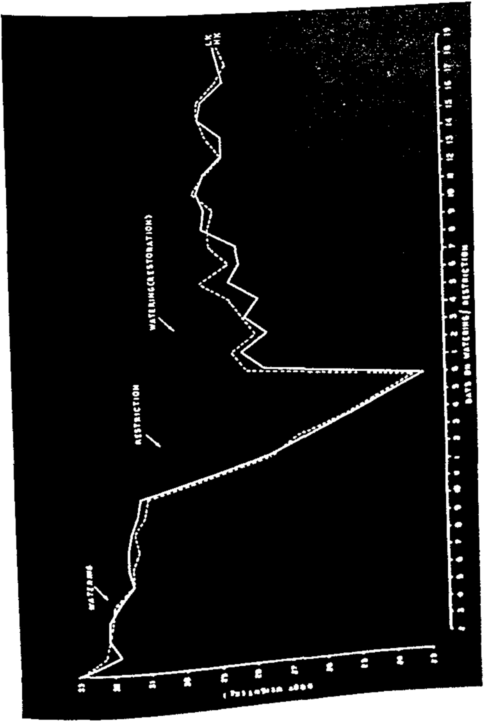
Table 3.—Results of analyses of variance of data on rise in body temperature in sheep during exercise

Source	Experiment No 1 d f.	Experiment No 1 M S		Experiment No. 2 d.f.	Experiment No. 2 M.S.	
Between exercise group	1	15.070**		1		
Between LK×HK	1	1.500*		1	4.792**	
Between days (replicate)	2	0.540	2 60	2	0.376	0 19
Error	43	0.250		50	0.192	

** Significant at 5% level of probability.
* Significant at 1% level of probability.

Another kind of stress which is frequently experienced by sheep in the desert is that these animals are driven daily for several miles for grazing and watering. The effect of this stress on animals belonging to the two potassium types was, therefore, investigated by trotting these animals at various speeds. It was found that during exercise the rise in body temperature in the LK type was significantly higher than in the HK type (Table 3). This rise in body temperature of LK animals was related to their ability to conserve body water as, after the exercise, these animals did not drink as much as the HK type animals. Physiologically, a rise in the body temperature above normal limits is detrimental to an animal and while selecting animals preference is given to those in which the rise in body temperature during stress is less. Although regulation of body temperature is generally considered to have priority over water balance, yet it may be logical to conjecture that in chronically water deficient areas the evolution of physiological adaptive mechanisms might have been directed primarily towards saving of body water. This would mean a necessary shift in the prerogatives for the stability of different physiological parameters. The thermo-regulatory behaviour of LK sheep, as discussed here, is probably a manifestation of such a generalised physiological principle aimed at fitting it properly into its desert niche.

The two important factors which may possibly explain the high proportion of HK in the Rajasthan desert are : (1) HK animals are resistant to diseases, and (2) they are in better health condition. We found that the HK animals have a significantly higher density of white blood cells. It would seem logical to conclude that HK sheep have


LK
HK
WATERING
RESTRICTION
WATERING(RESTORATION)
DAYS ON WATERING/ RESTRICTION

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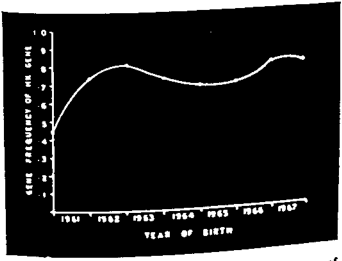
and wool and mutton production, the results achieved would naturally remain unused unless the genetic basis of these potassium types is investigated so that the knowledge gained on these types can be fully utilised by propagating the proper type and segregating and culling the undesirable one. We, therefore, investigated the genetic control of these two potassium types. Our results have confirmed the findings of earlier workers (Evans and King, 1955; Kidwell *et al.*, 1959) that the blood potassium types are controlled by a single mendelian gene. Results in Table 5 indicate that all HK×HK matings resulted in HK progeny, whereas HK×LK and LK×LK resulted in both HK and LK types. This indicates that HK is inherited as a simple recessive character and LK animals may be either homozygous or heterozygous. Results presented in Table 6 indicate that the differences between breeds within potassium types (LK and HK) were significant for potassium concentration. But there were no differences between breeds for the percentage of HK and for the estimated frequency of high potassium gene. It is possible that the differences for potassium concentration are of genetic origin and perhaps minor genes may be operating in addition to major genes which determines the potassium type of an individual. Experiments are now in progress to determine the relative importance of genetic and environmental factors responsible for variations in potassium



Text-fig. 4—Change in frequency of HK gene in relation to age of animal (year of birth) in Chokla flock.

a relatively better built-in disease resistance mechanism. We are now working out the differential counts which will throw more light on the subject.

Table 4.—Mean values along with Standard Errors for packed cells volume percent (PCV), hæmoglobin and red blood cell count, in LK and HK of Marwari breed of sheep

Type	Packed cell volume per cent (PCV)	Hæmoglobin (gm/100ml blood)	RBC (Millions/cm)
LK	29 73±0 29	9.11±0.26	10 62±0 20
HK	31.05±0.38	10.06±0 20	11.51±0.15

Difference between LK and HK is significant at 5% level of probability.

Another significant advantage of HK over LK animals is that the former remain in a sound condition of health. Our experiments have shown that regardless of the fluctuations in the pastoral condition during the year, the concentration of haemoglobin and the density of red blood cells are higher in the HK animals than in the LK (Table 4). A better health condition and resistance to diseases in HK animals should partly explain the high proportion of these animals in the Rajasthan Desert.

Table 5.—Potassium type of progeny from matings of ram and ewes of various phenotypes

Identification No.	Ram Potassium Type	Ewes LK(9 27)		HK (25 20)	
		Progeny			
		LK	HK	LK	HK
G 75	HK (26.24)	2(9.60)	2(29 22)	—	11(29.65)
G 423	HK (32.64)	1(9.60)	1(26.24)	—	10(30.78)
G 475	HK (32 64)	2(9 20)	4(34.08)	—	3(30 29)
G 988	LK (9 60)	2(10.21)	2(35 84)	6(30.62)	3(31 36)

Figures in parenthesis represent blood potassium concentration in Meq/l.

3. *Genetic Basis*

Since our aim is to determine the physiological differences between animals of the two blood potassium types in relation to their adaptation,

are now available from repeated experiments which clearly indicate that the low potassium type animals have, on an average, 16% lesser medullated fibres than HK type animals. In the britch and shoulder regions of the body LK animals have 20 to 26% less medullated fibres than HK (Table 6). Since our studies have also confirmed that LK are both heterozygous and homozygous whereas the HK animals are only homozygous recessive, the breeding of LK sheep and subsequent culling of HK segregating from LK×LK mating in each generation should result in raising flocks yielding true wool fibres. A survey of 4 breeds of Rajasthan has shown that the percentage of high potassium type (HK) is high (70%) in coarse wool producing breeds (Marwari, Malpura and Magra) and is low (52%) in a fine wool producing breed (Chokla). The association of LK with fine wool is, thus, very apparent. These results, therefore, may have immediate application for the rapid improvement of wool in most of the developing countries where sheep are largely of the hairy type.

IV—SUMMARY AND CONCLUSIONS

A resume of the work done in the Central Arid Zone Research Institute, Jodhpur, on the biochemical approach to the problem of animal production under arid conditions is presented here. The important points that emerge from our studies are (1) LK sheep have lesser medullated fibres and, therefore, have relatively finer wool. These animals can better withstand fatigue experienced during long walks in the desert in search of food and water, and a large proportion of this type drinks relatively less water and are therefore classified as "the desert type", and (2) HK are more resistant to disease and are in better health condition. It is tempting to believe that propagation of the LK type under optimum husbandry conditions may lead to a rational solution of the complex problem of wool production under arid conditions.

concentration within types. We have also made some observations on the frequency of HK gene at different ages in a flock of the Chokla breed. The animals on which the gene frequency has been established varied in age from 6½ years to 2½ months. Results in Text-fig. 4 indicate that except for those which were 6½ years old, the frequency for HK gene did not change with change in age and the observed low frequency of this gene at 6½ years of age may be due to sampling errors. It is, therefore, concluded that natural selection against these types is not operating in the flock under study.

Table 6.—Mean values for % medullation in LK and HK in Marwari breed

Position	September 1965 LK	September 1965 HK	March 1966 LK	March 1966 HK
Neck	54 2	63.2	65 4	74.6
Mid side	66 4	80.0	85.6	87.8
Britch	69.2	87.2	75.8	91.0
Wither	53 6	63.2	62.2	64.6
Shoulder	66 8	84 0	73.0	87.4
Back	61.8	71.0	60.8	67.2

Data transformed into arcsion $\sqrt{\text{percentage}}$ showed statistically highly significant differences (P. <. 01) *amongst types within region.*

4. *Relationship with Economic Traits*

Although our studies have given us adequate informations with regard to possible reason for the higher proportion of the HK animals in the Rajasthan desert, regarding the differences between the HK and LK types in adaptation to arid conditions and on their genetic background, the purpose of this study will not be fully served unless we find out the utility of the potassium type for improvement of wool and mutton production. In one of our experiments in which the potassium types were further sub-divided, LK being termed as alpha and HK type animals being grouped into 3 categories, viz. beta, gamma and delta, we observed that the beta and delta sub-types showed higher body and wool weight but the occurrence of these sub-types was rare.

We have recently collected data on body weight and fleece weight of sheep of several breeds and have determined their potassium types and the work which is in progress will elucidate whether potassium types have any association with the economic traits. However, results

SAFARI POTENTIAL OF RAJASTHAN

By

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Abstract

The countryside of Rajasthan was the happy hunting grounds of the princes and the British Officers during the pre-independence days where duck and imperial sand grouse shooting, pig-sticking with lance and horse, black buck chase by hunting cheetahs and tiger huntings were the special features of outdoor camps. Even now its dry deciduous open forests and the agricultural pattern of raising mostly one crop provide ideal habitat for wild life. The geographical location of the State is on the migratory birds' flyways, of both north- and southbound birds, and this feature enriches the avifauna of the State.

Every corner of the State is approachable, almost all the year round, providing easy accessibility to the wild life areas. Excellent visibility through the open bush presents clear views of the wild animals; concentrated waterholes make available the weary animals at close quarters; and the open sky throughout the year ensures excellent photographic opportunities.

The way of life of the people, who love all creatures, and their strictly vegetarian food-habits have gone a long way to help in the preservation of wild life. The undulating landscape, the Rajasthani heritage of unpolluted medieval culture, its temples, forts, fortresses and the rich archeological and cultural collections provide additional attraction for the tourist. Its location on the International tourists traingle, Delhi—Agra—Jaipur—Delhi, presents unlimited *safari* potential.

PIG - STICKING, A VANISHING SPORT OF RAJASTHAN

By

Kesri Singh

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Abstract

The wild boar, *Sus cristatus*, exists nearly everywhere in India. Its favourite habitat is the thick jungle on the hills or grass jungle near the water on plains, although it sometimes prefers the vicinity of a village, often selecting a sugarcane plantation in which it may take up permanent abode, never leaving it and attacking any one who blunders to disturb it. It varies much in size and in colour, and ranges from jet black to grey, reddish brown.

Its canine teeth are immensely long and turned upwards, forming tusks. The upper jaw contains two short tusks against the sharp edges of which the longer tusks of the lower jaw clash when shut and thus by continual friction their edges are kept sharp. The pug-marks of the male are distinguished from those of the female in being much wider in the heel and in having the toes much widely spread.

Pigs are gregarious animals and 20 or 30 of them may often be seen in a sounder. The older boar is more inclined to be solitary, sometimes in the company of another boar and will join the sounder only at the rutting season. Wild boars multiply at an alarming rate and at places become serious pests to the crops.

Pigs travel at a stumbling trot of about 5-6 miles per hour and maintain this pace for a great distance. Twenty years is probably the age-limit for a boar.

The wild boar has been hunted from times immemorial for its flesh and for sport by man on foot, armed with spear and aided with or without dogs. Pig-sticking is the most exciting and manly of sports in which the animal has at least an even chance to escape. Even when it goes down, it will sell its hide very dearly indeed. For its ferocity, it is the only wild animal to which the tiger will give a wide berth at the

OBSERVATIONS ON MATERNAL BEHAVIOUR IN THE LANGUR, *PRESBYTIS ENTELLUS*, IN INDIA

By

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(With 1 Table)

I—INTRODUCTION

During 13 months of observation on the langur *Presbytis entellus* (Dufresne) (family Cercopithecidae, subfamily Colobinæ) from July 1967 to August 1968, 11 cases of females carrying dead infants were observed in 9 troops around Jodhpur (Rajasthan). Of these, two cases—one in the non-mating and the other in the mating season—were followed regularly, with observations daily or on alternate days. The rest were followed less regularly. The present study deals with the keeping of the dead infants by the mothers and the degree of maternal urge and related behaviour by the concerned mothers and by the other members of the troop.

II—KEEPING OF DEAD INFANTS BY MOTHERS

1. General

Out of 11 infant deaths, 3 were newborn, found dead, and were considered as stillbirths; 6 were natural deaths due to unknown cause or by mishandling (suffocation or choking—inexperienced mothers press the infants hard during nursing and 'kissing', and during infant transfer from one female to another); 2 deaths were accidental—one due to fall and another to electrocution. All infants were breast-feeders (age below four months).

water hole. Pig-sticking was a hot favourite of the princes, but even outside the princely states in the pre-British India, several clubs existed, known as 'tent-clubs' at Meerut, Mathura, Kanpur, Nagpur, etc. With the exit of the princes, this manly sport has suffered a great neglect.

It is not difficult to create pig preserves as in every district there are jungles which are useless to the owner and these can be utilized for this purpose. If the place is already inhabited by wild pigs, it should be left undisturbed with a few chowkidars or game wardens to keep off the poachers and to kill jackals and wolves which destroy young pigs. By properly managing the pig-preserves, advertising the game and providing the customers with good horses and spears, a magnificent sport of international fame can be kept alive. If the Government or some private agency made it their business to make this sport possible for interested tourists seeking adventure, it would earn foreign currency and provide a great additional attraction for the tourists.

their breasts and brought them near the nipples in an attempt to feed them. They also tried to open the infants' eyes and frequently smell them. This attention gradually diminished, and the mothers started (after 5-6 days) putting down the dead infants on the ground sideways many times a day and picking them up again on the approach of an intruder or any slight disturbance or group movements. The process continued till finally the dead infant was abandoned.

Mating season : During the mating period the behaviour of the mothers towards the dead infants was less intense. Their unsocial nature, constantly watching the infant, 'kissing' and grooming, etc., of the infant were as in the non-mating season. But they began putting down the dead infants on the ground earlier (from the second day onwards) and more frequently, with occasional attempt at lactation. The mothers frequently watched the matings of other females in the troop, and ultimately abandoned the dead infant in some manner, as the mother was seen without the infant. How the corpse was disposed off could not be observed—presumably the mother just put it on the ground and walked away. The efforts of the writer at forcibly taking away the dead infant were not successful.

In both seasons, the mothers carrying the dead infant had a facial grimace (a distorted face); they also showed poor feeding activity, less antagonism towords troop-mates and were submissive. They were unusually sluggish, took very little interest in group activities and had a tendency towards isolation,

Condition of the infants : In cases of long retention (during the non-mating period) of the dead infants by the mothers, the skin and fur of the infant started disintegrating, leaving behind only the skull and bones with the shrivelled skin over them.

3. *Behaviour of Other Troop Members*

No troop member showed any interest in the females carrying the dead infants. Transferring of the dead infant from one female to another (as happens with living infants) did not take place. However, the subadults and juveniles of either sex were observed smelling and carefully watching the dead infants.

season (November to June next). In the non-mating season the keeping period was 9-29 days (average 15.5) and in the mating season 3-6 days (average 5.2).

Table 1.—Keeping of dead infants by mothers in Presbytis entellus *(Jodhpur, 1967-68)*

Abbreviations : F, female; M, male.

Location of troops around Jodhpur	Troop mark	Nature of death of infant	Approximate age (months) of dead infant when first observed	Sex of infant	Keeping of infant by mothers	
					Month(s) of the Year	Duration (days)
1	2	3	4	5	6	7
(A) In non-mating season (November to June next)						
1. Mandore	BT- 7	[Stillbirth]	–	–	February	11
2. Kaga	BT- 8	Natural	3	F	February	16
3. Chandpole	BT-10	Accidental	4	–	May	9
4. Guptaganga	BT-12	Natural	2	F	March	12
5. Kailana	BT-13	[Stillbirth]	–	–	May	18
6. Bhadreswar	BT-16	Natural	1	M	April-May	29
					Range	9-29
					Average	15.5
(B) In mating season (July to October)						
1. Mandore	BT- 6	Natural	3	M	July	3
2. Mandore	BT- 6	Natural	1	M	July	6
3. Kailana	BT-13	Natural	2	–	October	6
4. Bijolai	BT-14	[Stillbirth]	–	–	September	5
5. Filterhouse	BT-17	Accidental	2	F	August	6
					Range	3-6
					Average	5.2

Non-mating season : During the non-mating season, the mothers carrying the dead infant showed behaviour full of maternal sentiments exhibiting great attachment to the dead babies as if they were alive but passive. They always carried the dead infants in the manner in which they hold them if they are alive. During the first three days of the death of infants, the concerned mothers were seen observing them carefully from all sides, watching the eyes and the face again and again. They occasionally groomed and 'kissed' the infants, pressed them to

ultimately the infant was finally abandoned. The fate of the abandoned infant could not be determined.

The other members of the troop showed no interest in such mothers and the latter were left mostly to themselves.

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III—Discussion

These fairly prolonged observations made over two seasons suggest that at least some mothers show blind attachment to their dead infant, keeping them in their arms for surprisingly long periods (3-6 days in the mating and 9-29 days in non-mating season). This may at first sight suggest, as belived by Zuckerman (1932) for the Primates, that the langurs do not recognise the phenomenon of death, and this suggestion would seem to be supported by the continued attachment of the mother to the dead infant for long periods. However, it is to be noticed that the other members of the troop do seem to make a distinction between the dead and the living infants. For instance, they showed no interest in mothers carrying dead infants and there was no attempt at 'transferring' the infants as happens with living ones.

Jay (1962) in the langur *Presbytis entellus*, Prakash (1962) and Koford (1965) in the rhesus monkey *Macaca mulatta*, observed mothers carrying the dead infants. Koford stated that the corpse continued to be carried even after it had decayed, though the keeping period was not mentioned.

IV—Acknowledgements

I am much indebted to Dr. M. L. Roonwal, Vice-Chancellor, Jodhpur University, Jodhpur, for suggesting the problem and for his guidance and supervison. I also thank Prof. S.D. Misra for providing the necessary facilities for field work.

V—Summary

Eleven cases of dead infants being carried by their mothers were noticed in 9 troops around Jodhpur. The infants had died due to various causes. They were kept by the mothers for 3-6 days in the mating season and 9-29 days in the non-mating season. In cases of long retention, the infant had decomposed and was reduced to mere skin and bones.

In the first few days, the mother showed keen interest in the dead infant—hugging it, 'kissing' it, trying to open its eyes, bringing it to its nipples, etc. Gradually, the interest declined. After a few days, the mother started dropping the infant and picking it up again, and

INTERACTIONS AND SOCIAL CHANGES IN TROOPS OF THE LANGUR, *PRESBYTIS ENTELLUS*, IN INDIA

By

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(With 2 Tables and 3 Text-figures)

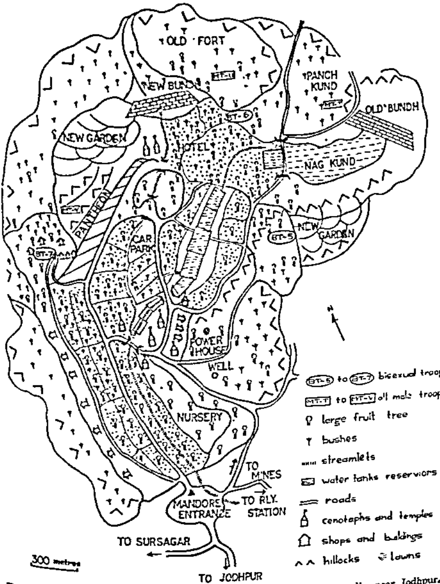
I—Introduction

Observations carried out on the behaviour of the Hanuman Langur, *Presbytis entellus* (Dufresne) (family Cercopithecidae, subfamily Colobinae) in and around Jodhpur (Rajasthan) during the period 1967-68, showed that social changes due to troop interactions were common in relatively compact habitats, particularly where many troops lived within a limited area, with similar ecological and topographical conditions. The Mandore Garden (Text-fig. 1), where the present observations were carried out, is 9 kilometres north-east of Jodhpur city, and is the only semi-natural green spot in the region—the rest of the are around Jodhpur being semi-arid, rocky and sandy.

Six permanent troops lived in and around the Mandore Garden of which 3 were all-males (Troop Nos. MT-T, MT-U, MT-V) and 3 bisexual (both sexes, with one male leader as a rule; Troop Nos. BT-5, BT-6, BT-7). Observations were made on troop composition, territory, home ranges, leadership, encounters and other interactions of social significance. In particular, the bisexual troop BT-6 was the centre of social change.

II—Ecological Distribution of Troops

The Mandore Garden is a semi-natural rocky garden (Text-fig. 2). Topographically, it has two distinct ecological habitats, viz. (i) the Central Part, with large stone cenotaphs, tall fruit trees, garden bushes, ornamental plants, spacious lawns, nurseries, water-tanks, small canals and streamlets; and (ii) the Peripheral Part consisting of a series of low hillocks and carrying arid zone plants, e.g. latex-bearing

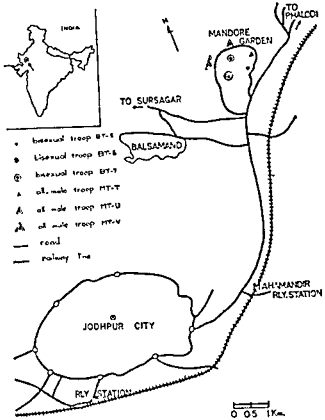


Text-fig. 2—Territories and home ranges of six troops of *Presbytis entellus* near Jodhpur. BT-5 to BT-7, bisexual troops; MT-T to MT-V, all-male troops.

III—TROOP COMPOSITION, TERRITORIES AND HOME RANGES

1. *Troop Composition*

All the six troops, comprising a total of 153 individuals of various ages, mingled in the Mandore Garden (Table 1). Each of the 3 all-male



Text-fig. 1—Location of the Mandore Garden and six troops of langur, *Presbytis entellus.*

euphorb *Euphorbia caducifolia,* trees such as *Acacia arabica, A. senegal* and *Salvadora oleoides,* the shrubby *Acacia jacquemontii, Leptadenia pyrotechnica* and *Tephrosia purpurea* and other xerophytes and cultivated twiners. The main garden extends over an area of *c.* 1 sq km (length 1.5 km, width 0.8 km).

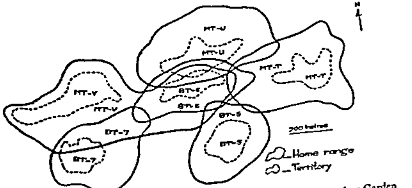
Large trees of *Ficus* (*F. religiosa* and *F. bengalensis*), the mango (*Mangifera indica*) and the neem (*Azadiracta indica*) which are present at the periphery of the garden served as night abodes of the 3 bisexual troops; these troops were often noticed as feeding in the heart of the garden. The 3 all-male troops belonged to the extreme peripheral part which is dry and rocky; here *Salvadora* and *Acacia* trees served as night rests for these troops.

Table 2.—Presbytis entellus. *Territories and home ranges of some troops in Mandore Garden near Jodhpur*

	Troop mark	Territory (hectares)	Home range (hectares)	Proportion Territory	:	Home range
All-male	MT-T	9.6	35.9	1	:	3.7
	MT-U	8.7	33.8	1	:	3.8
	MT-V	11.9	59 8	1	:	5.0
	Range	**8.7-11.9**	**33.8-59.8**	1	:	4.1
	Mean	**10 6**	**43.1**			
Bisexual	BT-5	6.8	21 0	1	:	3.0
	BT-6	7 1	20 8	1	:	2.9
	BT-7	6.2	19 6	1	:	3.1
	Range	**6 2-7.1**	**19.6-21.0**	1	:	3.3
	Mean	**6 7**	**17.1**			

2. *Territories and Home Ranges*

The areas of the territories and home ranges of the six troops are given in Table 2. The 'territory' of a group is the limited area which is frequently used by the troop individuals for resting, grooming and feeding purposes during the day and sleeping during the night. Overlapping of territories was observed between two troops, viz. the all-male MT-U and the bisexual BT-6. The territories of the bisexual troops are more demarcative and clear than those of the all-male troops (Text-fig. 3).



Text-fig. 3—Ecological distribution of six troops of *Presbytis entellus* in the Mandore Garden near Johhpur.

Table 1. —Presbytis entellus. *Social composition of troops in Mandore Garden near Jodhpur*

Abbreviations : A, adult; SA, subadult; WJ, weaned juvenile; J, juvenile (breast-feeder); I, infant (breast-feeder)

Troop mark	Composition and number of individuals										Total
	A♂	A♀	SA♂	SA	WJ♂	WJ♀	J♂	J♀	I♂	I♀	
					All-Male Troops						
1. MT-T	4	–	–	–	–	–	–		–	–	4
2. MT-U	6	–	4	–	1	–	–	–	–	–	11
3. MT-V	9	–	7	–	7	–	–	–	–	–	23
									Range		4-23
									Mean		12.6
					Bisexual Troops						
1. BT-5	1	11	–	3	–	3	1	2	1	3	25
2. BT-6	1	18	–	4	6	4	2	3	2	1	41
3 BT-7	1	21	–	5	3	4	3	5	3	4	49
									Range		25–49
									Mean		38.3
						Both types of troops		Total			153
								Mean troop-size			25.5

troops had 4-9 adult males, with a leader, while each of the 3 bisexual troops had 25-49 individuals, with a male leader as a rule. (If the small area in which these 6 troops lived is taken into consideration, this habitat had a rather high population as compared to other habitats around Jodhpur.) The average troop-size was 25.5 individuals (12.6 in the all-male troops and 38.3 in bisexual). The combined male : female ratio of all the members of all the 6 troops was 1 : 3, but the adult male : female ratio was 1 : 2.3. In other parts of India and Ceylon, Jay (1965) and Ripley (1967) gave the average troop size as 25 and Sugiyama (1964) as 15.1.

the territories of the two troops overlapped. (No other member of MT-U was seen having these interactions with BT-6.) These interactions developed tolerance of his presence near the females of BT-6, even against the wishes of the male leader of BT-6.

In the first week of July 1968, when the ranking male of MT-U attempted the mounting of estrus females of BT-6, he was prevented from copulating by the male leader of BT-6 who chased him away again and again. There were several fights between them in which they inflicted wounds on each other. All the combats were undecisive, and the ranking male did not return to his troop but stayed near BT-6.

In the second week of the July, 3 estrus females were observed presenting themselves before their male leader and the ranking male of MT-U. The leader copulated successfully, but the ranking male did not succeed in doing so because of constant meddling by the leader. Both of them barked at each other and bared their teeth; with hard grinding of canines and whoop calls the leader chased away the ranking male. Occasional biting and slapping between them was also noticed. But by mid-July the ranking male had succeeded in his efforts and was seen copulating with BT-6 females. The leader male was now avoiding confrontation with the ranking male, but at times tossed its head and barked at the latter. The ranking male was fully tolerated by the other troop members, particularly the females towards whom he was very mild, and by the early third week of July he had fully attached himself with this new troop, BT-6—he participated in all its group activities including night rest on the same tree.

3. *Attacks of All-Male Troops MT-V and MT-T on the Bisexual Troop BT-6*

(a) Attack of MT-V

Troop MT-V, which was the largest (9 males, all adult) of the 3 all-male troops, often invaded the garden for food and to gratify the sexual urges. Before June 1968, its visit to the interior of the garden were less frequent, but in early July it was seen more often around the garden. Since its home range overlapped those of the 5 remaining troops (2 all-males and 3 bisexual), it was obliged to take long detours in order to avoid trespassing the territories of the other troops.

In mid-July it attacked the bisexual troop BT-6 twice, but the

The 'home range' of a troop is the total area in which a troop moves about on certain occasions away from its territory during group progression in all seasons, and is thus more extensive than territory. The home ranges of the bisexual troops were about three times their territory. The home ranges of two all-male troops (MT-T and MT-U) was nearly four times their territory and of the third, MT-V, five times. The large areas of the home ranges have resulted in their overlapping to a certain extent.

IV—Happenings in the Bisexual Troop BT-6

1. *General*

From late June to late August 1968, the bisexual troop BT-6 was the centre of intense social interactions with the three all-male troops (MT-T, MT-U and MT-V) because of its various deficiencies. Troop BT-6 had a nervous and insufficiently aggressive male leader. Its territory overlapped that of the all-male troop MT-U. Its home range overlapped those of all the 3 all-male troops, and also the bisexual troop BT-5 and BT-7. The bisexual troop BT-6 had the maximum number of fruit trees at its disposal, and was observed feeding and resting during the day in a less cohesive manner than the other troops, resulting in poor vocal and auditory coordination regarding warnings of danger, etc. It had an exposed habitat which allowed easy access to the all-male troops for food. The regular availability of estrus females in troop BT-6 and their quick presentation often attracted the adult males of the all-male troops, resulting in both exhibition and true fights.

2. *Behaviour of Ranking Male of the All-Male Troop MT-U towards BT-6*

The ranking male of the all-male troop MT-U was an adult having a strong body-build and with fully erupted canines. He was classified as a 'ranking male' because, except for the leader male of the troop, all other males in the troop were submissive to him. He himself was neither submissive nor dominating in relation to the leader of MT-U, though he avoided the leader during group activities. Prior to late June 1968, the ranking male was seen near the bisexual troop BT-6, engaging mostly male weaning juveniles—embracing, 'kissing' and lifting them. They had enough opportunity of mutual contact, since

ness of the leader male even though the ranking male helped him to resist attacks of the intruders. But due to constant attacks, particularly of the nine adult males of MT-V, the male leader of BT-6 could not bear the weight of attacks, and ultimately, by the end of August, abdicated along with 6 weaned male juveniles, forming a new all-male troop of 7 individuals with himself as the leader.

The ranking male then became the leader of the remnant of BT-6 (35 individuals). He fought furiously in all attacks by intruders and always gave cover and protection to the females. These conflicts were mainly for acquiring estrus females to gratify the sexual urges of the attacking males. It is probable that abundant food supply and the less protected habitat available to the bisexual troop might also have attracted the attacks.

The abdication and departure of the ineffective male leader along with a few male juveniles from BT-6 also resulted in the installation of the more powerful ranking male as the leader—thus restoring a 'single leader' pattern which seems to be the rule in *P. entellus.* Sugiyama (1964) also observed a one-male leadership in this species.

V—ACKNOWLEDGEMENTS

I am much indebted to Dr. M.L. Roonwal, Vice-Chancellor, Jodhpur University, Jodhpur, under whose guidance and supervision this study was carried out. I also thank Professor S.D. Misra for the necessary facilities for field work.

VI—SUMMARY

Social changes were studied in six troops (3 all-male and 3 bisexual) of the Hanuman Langur, *Presbytis entellus*, inhabiting the Mandore Garden near Jodhpur (Rajasthan). The average troop size was 25.5 individuals which is rather less than the size found in other troops around Jodhpur. The bisexual troop BT-6 underwent the maximum changes, due mainly to attacks of the adjacent all-male troops during July and August (the mating season). The attacks were principally for the possession of estrus females. An intruding ranking male from the all-male troop MT-U, after repeated attacks on BT-6, installed himself as the new leader, and

attacks were mild and were successfully repulsed by the male leader of BT-6. On one occasion the new 'ranking male' (who was by now a part of BT-6, *vide* above) also participated in chasing away the MT-V males, though neither he nor the leader male indulged in a direct fight.

Subsequent attacks of MT-V males on BT-6 were more furious but still unsuccessful, and MT-V males withdrew after each attack. During these attacks it was noticed that a young adult male of MT-V led the attack, and the other adults kept in the background, but as soon as this young adult started fighting with the male leader of BT-6, the other males of MT-V also invaded BT-6. Such fights were observed throughout July. Regularly in the evening after fights, they returned to their permanent abode. In August, estrus females of BT-6 were seen presenting themselves before the males of MT-V. This resulted in severe fights between the intruder males and the ranking male of BT-6. The leader male of BT-6, however, gave poor performance and merely grimaced—apparently he had little physical power to resist the invaders. On the other hand, the ranking male fought hard, strongly resisted the intrusion, and did not allow the invader males to mount the estrus females even though the latter presented themselves before the intruders. The adult males of MT-V, were seen staying overnight near and around BT-6. In late August the intruder males succeded in acquiring two estrus females after a long and hard combat with the ranking male of BT-6 who was virtually playing the role of the leader.

(b) Attacks of MT-T

The all-male troop MT-T also attacked the bisexual troop BT-6 many times during July and August 1968. But the attacking males were mostly chased away by the ranking male and sometimes by the male leader. Only once were they seem to succeed, when a young MT-T adult copulated with a BT-6 female.

4. *Discussion on Social Changes*

Due to repeated attacks by the all-male troops MT-V and MT-U on the bisexual troop BT-6 during July and August 1968, the latter troop became greatly disorganised and their gatherings during feeding, resting and troop movements were loose. During night also, BT-6 members took shelter in many trees instead of their few permanent resting trees. This disorganisation is mainly attributed to the nervous-

CONSERVATION OF THE INDIAN LION*

By

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I—Introduction

Those of you who followed the newspaper reports of the recent government census will know, the world's total wild population of the Indian lion now numbers less than 200. At one time the range of the Indian lion extended as far west as the Mediterranean, and linked up with that of its African cousin. The earliest mammalian extinction that we know to be at the hand of man was the European lion in approximately 100 A.D. With the advent of modern firearms the Cape lion in South Africa met a similar fate in approximately 1865, followed by the Moroccan and Algerian lions in approximately 1890. The Asiatic lion was virtually exterminated in Palestine during the Crusades, but remained rather strong over most of its former range until the 1800's when it too was severely decimated, the most significant reductions occuring when well armed military personnel occupied part of the lion's range. Since 1884 the last real population of Asiatic lions has been limited to the Gir Forest, India, with the exceptional individual still turning up in the Middle East, even as recently as 1942.

Thus the Asiatic lion has now joined the ranks of the world's rarest species, along with the Javan rhinoceros, the Spanish lynx, the North American whooping crane, the Australian hairy-nosed wombat, and a host of other species which, after the most careful considerations by the International Union for Conservation of Nature and Natural Resources, now exceeds 1000 species and races of vertebrate animals. To put the lion in its proper perspective, nearly 40 per cent of the mammal losses alone have occurred within the past 50 years, and of these more than half (54 per cent) have been the larger predators. In

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*Only a century ago, the lion formed a part of the Rajasthan fauna. —Editors.

the old male leader left BT-6 along with a few male juveniles to form a new all-male troop.

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To a very great extent the forestry and cattle are in competition for the use of the land, and it is only by the most careful protection of the plantation areas that regeneration of trees is possible. In the last 100 years the size of the Gir Forest has contracted from 1200 square miles to something less than 500. At the height of the dry season when the ground is clear of vegetation the *maldhari* are forced to prune the trees in order to provide food for their stock. Understandably, the pruning of teak is strictly prohibited, but the impact on the other less commercial species is shocking in some areas. Despite government aid to the farmers in the way of food stuffs, years of severe drought result in considerable livestock reductions.

The third major interest is tourism. A guest house is situated at Sasan; and each day visitors are taken from here to see the lions. It is a unique opportunity to be able to observe these majestic creatures without any encumberance, such as having to sit in your car, as is the case in Africa. At the present time the net return is nil, and in fact the guest house establishment is being run at a loss. There are many reasons for this, but the main one, in my belief, is that there is little else for the tourist to spend his money on, other than by seeing lions, and after paying 80 rupees per small party he is unlikely to do this twice during his visit. There are no posted trails that he can walk on, there is very little wild life to be seen, there is nothing to indicate where he might go if he wishes to see any of the natural beauty spots, there are no postcards he can purchase to send to his friends, there is no interpretative programme in the way of slide shows, talks or tours, there are no maps, no displays. In fact, beyond the lion shows and the guest house there is nothing to induce him to stay overnight, and indeed most of them do not. The tourist industry obviously needs some stepping up if it ever hopes to compete.

The conservation of the lion is yet another interest, and the reason behined why I am speaking today. I think there is no doubt in the minds of anyone attending this resource conference, that the lion ought not to disappear. It is unique and ought to be preserved because its the only lion living in a free state in the whole of Asia. It lives in a forest and is easily approachable unlike its African cousin. It is of national interest, already deeply ingrained in the culture of the Indian people and immortalized in the tri-headed seal of the government. It is of considerable scientific interest in the light of the current

other words, the lion's disappearance is associated not just with the fact that it is a lion, but rather its being a predator, which like all of the larger predators, competes with man by preying upon his domestic and wild stock. Moreover, because it is a predator, it must, by necessity, be *few in number in the natural state*, at least in comparison to its prey. One lion, for example, might consume 50 zebras in the African savannah during the course of a year. In so far as the extinction of either is concerned, they usually exist in the free-living state in such ratios, and to destroy one lion would be equivalent to destroying 50 zebras. To destroy one tiger might be equivalent to destroying 100 wild boar. To destroy one snow leopard might be equivalent to destroying 300 hare. *This is why predators, of which the lion is an example, are so much more vulnerable to extinction than any prey species is likely to be.*

II—PRESENT POSITION OF THE LION IN GIR

Now with that background let me describe for you briefly the situation in the Gir Forest. The sanctuary is approximately 500 square miles in size. More than half of it is teak and occupies the central and western portions. *It coincides largely with the highest lion population figures obtained for any area during the census.* The remainder is made up primarily of *Acacia* thorn scrub, with about ten per cent being given over to agricultural encroachment and village sites.

It is inhabited by 8000 people, most of whom are *maldhari*, and depend on the raising of buffalo for *ghee* as the source of their economy. They maintain approximately 16,000 heads of buffalo at the present time, and an equal number of *other assorted stock ranging from cows to camels. During the monsoon when the surrounding lands are under cultivation*, the villages outside of the sanctuary are given permission to bring their stock inside for grazing. They are again permitted entry in the dry season during scarcity years, and this year it is expected that they will be coming from as far away as Rajkot and the Rann of Kutch. *As many as 80,000* heads have been known to enter during *this period*, and in this respect the area becomes more of a cattle sanctuary than a wildlife sanctuary.

The *other interests* of importance are forestry and *tourism*. The *teak forest* is of low grade, class three or four, and is *maintained* on a 40-year rotation. It supports a probable net return of something in the order of five or six lac rupees yearly.

guarantee the tourist that he would see at least something in a day's travel, but that they would again constitute an important part of the lion's diet as they presumably once did. Although this requires further study, a reduction in the competition between wildlife and domestic stock for food and water would probably be sufficient. However, it should be pointed out that there are several hundred firearm holders in the sanctuary, and hearing shots at night is not uncommon, suggesting that there may also be a poaching problem to deal with. I don't understand why firearms are permitted in the first place in a wildlife sanctuary.

3. Cattle numbers should be limited to a level which will assure that no further deterioration of the habitat will take place. It is short-term thinking to permit the area to be used as a cattle sanctuary beyond its carrying capacity, and beyond the compatability of the other interests. That is not to say that they should be excluded entirely at the stroke of a pen, for I have no doubt that that kind of action would result in the lion's starvation.

4. My fourth and final recommendation concerns the tourist industry. To save the lion just because its rare is not enough to convince the politicians who also have to deal with the grievances of the *maldharis* and others affected in the process. Rather it seems only right that the lion should be capable of paying its own way, both in terms of the numbers of visitors that it attracts and in the revenue which it incurs. And as far as the lion is concerned the only way that this can be achieved is through tourism. At the present time the tourist industry is running in the red. Many of the improvements required are not expensive, e.g. providing marked trails, marked sites of natural beauty and which are to be made known to the tourist, postcards and an interpretative programme. But some of the improvements required are expensive, viz. as a tarmack road between Keshod airport and Sasan, and again another half a dozen miles between Talala and Sasan, the other major route by which visitors come. If the results of such improvements done in other sanctuaries and national parks can be taken as comparable, then the income in tourist traffic should be dramatic and all towards the conservation of the Indian lion.

In conclusion, it is with considerable pleasure that I read of the recent announcement by the Gujarat Government to accept the conversion of the Gir Wildlife Sanctuary into a National Park in principle. Now it

African investigations. Its potential in the teaching of conservation to school children is tremendous. I dare say that there is not a single school boy who would not be thrilled at having a chance to see the lion. But all the reasons I have given do not cut much ice in the face of existing problems. The results of my studies thus far have indicated that the lion is living almost entirely on domestic stock, and probably because there is very little wildlife to feed on. Yet he dose not find it to be all that easy to kill, and indeed tends to select the smallest prey, such as young buffaloes or cows. When he is successful in making a kill he is usually driven off it, and the *harijans* take the meat. This is particularly true in the eastern half of the Gir. And to compound the lion's difficulties in the eastern Gir the landscape is open, so that it is all but impossible for the lion to make a kill without being seen in the process, and worse still to have it taken from him when he is successful. On the other hand, the lions in the western ranges are making their kills in the dense teak forests, and appear to be more successful, killing more than one animal on about a third of the cases which I have investigated. Presumably the *maldhari* finds it more difficult to protect his stock in the forest. Moreover, for reasons which I do not yet understand, less kills appear to be taken away by the *harijans*. My guess is that the *harijans* have greater difficulties in locating the kills in the forest. The differences between the western and eastern ranges are correlated with the differences in the number of lions, the western ranges having about twice as many lions, if not more, than the eastern ranges.

III—Recommendations

Although there are many recommendations which I should like to make there are a few which I consider to be paramount.

1. The *harijans* must be stopped from taking the meat from the lion kills. It is absolutely not in keeping with conservation of the lion. I do not know the social aspects to this problem, but I understand that the meat they take constitutes only a small supplement to their income. On the other hand, the *maldhari* is likely to benefit, for the lion would not have to make so many kills just to get enough to live on.

2. Steps should be taken to increase the numbers of the other wildlife species, such as the nilgai, sambar, chital and 4-horned antelope, with the ultimate hope that not only would they be common enough to

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remains to be seen how much they can do in the way of bringing principle into practice.

IV—Summary

After tracing the history of the Asiatic lion in West Asia, the *auther discusses its precarious position in the Gir Forest Sanctuary in* Gujarat, Western India. Some recommendations for its conservation are made.

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